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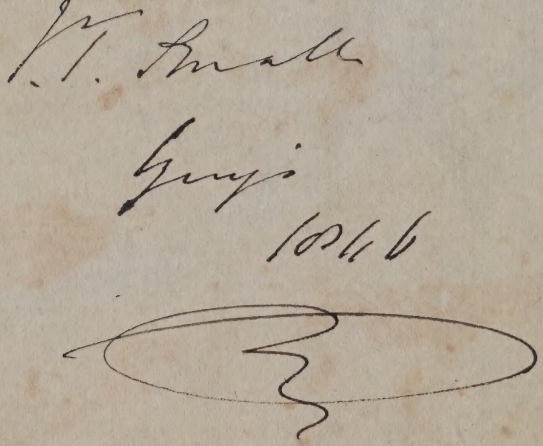

Bot. Gen. B.

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BOTANY.

IN FOUR PARTS.

1. STRUCTURAL BOTANY.
2. PHYSIOLOGY.
3. SYSTEMATIC BOTANY.
4. DESCRIPTIVE BOTANY.

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BOTANY.

BOTANY is that branch of natural history which relates to the structure, vital action, classification, and uses of those objects in the organic world which we call plants. In the language of some persons, indeed, it is confined to a mere explanation of the art of classifying plants, and to the power of using such classifications so as to ascertain the name of a given species with certainty; by others it is allowed to comprehend a knowledge of the various kinds of structure which we meet with in the vegetable kingdom, but scarcely to extend beyond those two departments. But, in reality, the former of these objects, however important, is only a collateral branch of the subject; and the latter is but a portion, although an essential one, of those investigations from which botany derives its claim to the rank of science.

The study of the works of nature, independently of its contributing in a powerful degree to elevate the mind of man, and to bring him into communion with his Creator, is of great consequence, as being the means by which he is enabled to compel all living things to minister to his comforts, his pleasures, or his necessities. It is to the latter objects, chiefly, that naturalists usually direct their attention; because it is justly supposed that all higher considerations of necessity grow out of the investigations in which we must engage, in order to apply any branch of natural history to practical purposes.

The properties of vegetable productions, with reference to their utility to mankind, are influenced by the species or varieties from which they are derived; by the mechanical structure or chemical composition of the part of the plant made use of; and by the phenomena and changes connected with the action of the vital principle of vegetation, which may be considered either independently of external circumstances, or when controlled either by natural causes or by artificial means. In order to apply the knowledge of such objects usefully, and to render it available to others, arrangement and method are indispensable; not only in regard to the ideas derived from a consideration of the nature of plants, but in regard to plants themselves.

Hence four grand divisions of the science of botany into—

I. STRUCTURAL BOTANY; which comprehends whatever relates to the laws of vegetable structure, whether external or internal, independently of the presence of a vital principle.

II. PHYSIOLOGICAL BOTANY; to which belongs all that concerns the history of vegetable life, from the moment when the vital principle is imparted to the seed and the plant first breaks its shell, to the period of death: explaining the functions which the various organs are destined to perform; the changes they undergo in health or sickness, and under all the influences exercised by climate, seasons, accidents, or the art of man.

III. DESCRIPTIVE BOTANY; from which we learn the art of describing plants with accuracy, so that their characters may be recognized with certainty by others, and of giving to plants names by which they can be mentioned without confusion when written or spoken of.

IV. SYSTEMATIC BOTANY; which explains the principles upon which are determined the mutual relations that combine the seemingly discordant members of the vegetable kingdom into one harmonious whole; and which teaches the art of distinguishing any plant from all others, so as always to determine its name with precision.

These subjects we shall treat in the order in which they have been mentioned.

Part I.—Structural Botany.

Chapter I.

A general view of the external Structure of a Plant complete in all its Parts.

A PLANT is a living body, deprived of sensation or power of moving from place to place, and fed by means of external roots.

Animals, on the contrary, are endowed with sensation and the power of voluntary motion from place to place; and are fed by means of an internal bag consisting of one or more stomachs.

These differences are readily enough observed between animals and plants of the higher and more perfect grades; but there are many of the more minute, and apparently more simple, kinds which it may appear difficult to refer with certainty to either of the above classes. Aquatic animals of the polypiferous kind, for instance, have not only very much the appearance of a plant, being attached to rocks by a sort of root; but actually grow, as plants do, by the continual emission of new branches. Marine plants, like these animals, derive no food from their apparent root, and seem to have a sort of universal external stomach; while some of the minuter kinds of filamentous aquatic plants or sea-weeds, after being detached from the soil by accident or otherwise, continue to grow as they float in the water, and often appear to have a certain degree of motion, when it may be difficult to ascertain with certainty whether it be owing to internal volition or to external physical influences. In these cases the mode of nutrition is the only certain test by which the objects in question can be referred to one of the great kingdoms of animals and plants.

It is, however, obvious, that whatever difficulties may attend the distinguishing of plants from animals in particular cases, their differences are, generally, sufficiently apparent. Without occupying ourselves, then, with a question which belongs to the theory of creation more than to botany, let us cast a hasty glance over the structure of some plant in which is present every organ that is usually met with in what we consider a species complete in all its parts.

Such a plant is the violet (Viola odorata), or the heart's-ease (Viola tricolor). The latter consists of a number of green, or yellow, or purple parts, arranged symmetrically upon a green angular axis, which puts forth under ground many slender whitish threads, divided in an irregular manner. The green angular axis (*fig.* 1, *a*) is the *stem*, the slender threads (*b*) are *roots*.

Upon the stem are placed, at equal distances, certain flat, green, toothed bodies, which gradually taper into a thin stalk; it is almost superfluous to say that these are *leaves* (*c*). At the

Fig. 1.

base of each leaf are placed two other thin green parts (*d*), which are very like the leaves, only they are smaller, and are deeply gashed near the bottom instead of tapering into a stalk; to these is given the name of *stipules*.

The axis, consisting of stem and root, together with the leaves and stipules, forms the *organs of vegetation;* so named because they have no other destination than to enable a plant to

live and grow, and perform those vital actions which are not connected with the office of spontaneous propagation.

From the angle (*e*), formed by the junction of the leaf with the stem, which is called the *axil*, springs a slender angular stalk, on the top of which the flower is seated. This stalk, called the *peduncle*, has, near its upper end, a couple of little scales (*f*) named *bracts*, which are of a nature intermediate between the organs of vegetation and those of *fructification*. The latter name is given to the parts of a flower, because their office is exclusively to enable a plant, by fructifying, to multiply its species spontaneously.

The *flower* consists, externally, of five small, narrow, green leaves (*g*), called *sepals*, and of the same number of larger yellow and purple leaves (*h*), called *petals:* the sepals taken collectively form a *calyx*, and the petals, in like manner, form a *corolla*. These two are often named *floral envelopes*.

Within the petals, and quite hidden from view by the bases of those organs, until they are pulled off, is a row of five thin, pale-yellow parts (*i*) sticking together a little by their edges, but separated from the body they surround; they are named *stamens*, and are the fertilizing apparatus of the flower. They surround a hollow body (*k*) tapering into a zigzag cone, and terminating in a globular head: this is the fructifying apparatus, and is called the *pistil;* within its hollow base may be found the young seeds, which we name *ovules*, from their resemblance to little eggs, or *ova*.

By certain curious operations, which need not now be explained, the pistil is fertilized; after which it swells, alters its form and texture, and at last becomes the *fruit* (*l*), which is hard and dry, splits into three pieces, and sheds the seeds which, by that time are ripe and fully formed. The seed (*m*) consists of a shell, containing a quantity of fleshy matter (*o*), from its resemblance, in use, to the white of an egg, called *albumen;* in the midst of which lies an *embryo* plant (*n*), which is supposed to be nourished by the albumen until it breaks the shell and is strong enough to gain its food for itself.

Such is the heart's-ease; such are the organs which constitute the fabric of all the most perfectly constructed plants. Lowly a species as it is, it comprehends every part that is employed by nature in the formation of the loftiest tree of the forest; the difference in size between it and a tree being caused by nothing more than an endless multiplication of similar parts of vegetation, constructed always upon a similar plan, adjusted to each other in the most admirable manner, and all working in perfect harmony and order. The stem in the heart's-ease perishes every year; in an oak it lives from year to year and from age to age, constantly augmenting in size. This, however, is not owing to any material difference in the structure of the two species, but to a specific power of prolonged vitality in trees, which plants like the heart's-ease are destitute of. To make this more intelligible, suppose a heart's-ease to produce, in the course of the first year of its life, a stem with twenty leaves, and that its stem is hard and perennial, instead of soft and annual. In the second year, its stem, by virtue of a power hereafter to be explained, may form a new branch at the axil of each of its twenty leaves; and as the second branches may be as large, at least, as the first, it may, therefore, multiply its dimensions twenty times. In the third year the same operation may take place; and the consequence of this will be, an augmentation equal to four hundred times its original dimensions; and so on in a geometrical ratio. At this rate a heart's-ease would soon develop into an enormous tree; and although that species never does so change its nature, yet it is quite true that every tree, in the first year of its existence, is formed upon a plan analogous to that of the heart's-ease, and never more complicated; and that its subsequent growth into a giant of the forest takes place upon the plan that has just been adverted to in a supposititious case.

The adaptation of all these parts to the maintenance of a perfect system of life, in which each organ performs its allotted office with unvarying regularity and with the most admirable harmony, so that no one interferes with another, is among the most beautiful instances of contrivance in the creation. It is the especial business of physiological botany to explain this, which will therefore be the subject of detailed illustration hereafter. In the meanwhile, a brief exposition of the

leading functions of the several organs will render the account we shall have to give of their structure more interesting to the general reader than it otherwise would be.

The root is the part which attracts the liquid food of plants from the soil in which it is mingled, and impels it upwards into the woody part of the stem. Once introduced into the system of a plant, this food becomes altered from what it originally was, and is called *sap*.

Sap rises through the woody part of the stem, dissolving what soluble matter it meets in its passage, and at last is impelled into the leaves. Having arrived in those organs, it loses water by evaporation; peculiar chemical changes are produced in it by exposure to solar light; and at last, having been converted into the secretions peculiar to the species in which it is formed, it is returned from the leaves back into the stem, down which it descends, through the *cortical layer* or bark, passing off laterally into the centre of the woody matter in its downward course. In the bark and the centre of the stem a considerable proportion of the peculiar secretions from the sap is finally stored up, and eventually all those substances which it is necessary that the plant should get rid of are passed off into the earth again by the roots. Thus an ascending current of crude sap, a descending flow of elaborated sap, and a lateral deposit of the latter in the stem, are going on during all the time that a plant is in a growing state; and, in consequence of special routes being assigned to each of these currents, they act without in the slightest degree interfering with each other. By what particular vessels and by what microscopic apparatus this vegetable laboratory is kept in action, will be fully explained hereafter.

In the flowers the calyx and the petals may be supposed to act to a certain extent as leaves, to furnish food for the stamens and the pistil, which are enclosed within them. The stamens and pistil continue to increase with equal steps up to a certain period, which is the maturity of the former, and the commencement of a new growth in the latter. At this time the upper part of the stamen bursts and discharges a fine powder, the motes from which fall upon the tip of the pistil, which, at that particular time, becomes viscid, for the purpose of causing the motes to adhere to it. Here the motes, which in reality are hollow globes, filled with fertilizing matter, absorb the circumambient moisture, distend, and at last discharge upon the humid point of the pistil that matter whose mysterious influence is to cause the pistil to fructify. This accomplished, the stamens wither and die; but the pistil, to which a new life has been thus imparted, goes on growing and swelling; the ovules distend, and occupy all the cavity of the pistil; in their inside a little being is born, which feeds upon the liquid albumen, and at last assumes the form of a microscopic plant. When this takes place, the parts of the pistil lose their green colour, and assume the livery of death; the integuments of the ovule harden, seeds are formed, and in order to enable them to escape from the prison in which they are locked up within their parent fruit, the sides of the latter give way, either by rending, or splitting, or decaying, and allow the seed to fall upon the earth. There it lies till the hour for its further progress is at hand, when the moisture in the soil becomes warmed by the rays of the sun; a stimulus is thus communicated to the embryo plant, which swells, lengthens, pushes forth a tiny root through an opening in its shell, and at last disengaging itself altogether from its hard integuments, unfolds its little leaves, rears its stem into the air, pushes its roots down into the soil, and thus establishes itself as a new individual, with power to bear all the organs, to undergo all the vicissitudes, and to accomplish the same destiny as the parent from which it sprang.

This may be considered a correct view of the course of many a vegetable life; no doubt, there are many modifications of all these phenomena, and even some exceptions to them, but with these we are not to occupy ourselves in the present place.

Chapter II.

Of the degree in which perfect external Structure is departed from.

Although all the parts just named concur in the formation of a plant of the most perfect kind, there is not one of them that, in one species or another, is not either altogether wanting, or so altered in its nature as scarcely to be recognised. The root itself, by

which the food is conveyed into the body, is scarcely present in such marine plants as seaweeds, and even in the dodder (Cuscuta) which grows upon heaths, and the mistletoe, which fastens itself as a parasite upon other species, it is so rudimentary as to be scarcely capable of action.

The stem in numerous species is so short as to be almost invisible. Leaves are frequently mere scales which drop off almost as soon as they are formed, leaving the plant to shift for itself by the aid of other means, as is the case in cactuses, stapelias, and the like. Both leaf and stem are so blended into one body in the duckweed (Lemna) that it is difficult to say whether the part that really exists is the one or the other. Stipules are as often wanting as present. Bracts, in like manner, are frequently missing. Of the floral envelopes, sometimes the corolla is absent, as in the mezereon; and sometimes both calyx and corolla, as in the willow.

Even the stamens and pistils themselves disappear in a large number of plants. It is, however, to be remarked that this latter circumstance is always attended with a corresponding imperfection in the whole of the other organs, and is, therefore, before all other things, considered an indication of a greater degree of general imperfection. Ferns, for instance, in which this occurs, have neither calyx nor corolla, nor is their stem like that of other plants; in mosses, moreover, the leaves are mere scales; in lichens, the whole plant consists of but a flat plate composed of leaf and stem combined, with nothing for their seeds but excessively minute transparent bladders; and, finally, some confervæ and fungi are destitute at once of every one of the usual organs, consisting of nothing but a cell or two of exceedingly small size, in which the essence of root, stem, leaf, flower, and fruit, without the form, is supposed to be comprehended.

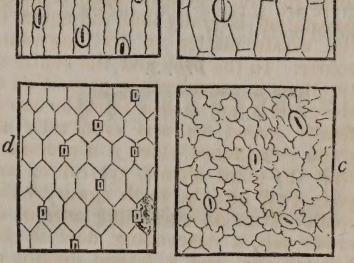
From these causes the diversity of appearance in the vegetable kingdom is very great. But an examination of all the organs in detail will show that every species is in that state which is best adapted to the purpose for which it is destined; and that plants, from the extremely simple plan upon which even those which are apparently most complicated are organized, offer peculiar facilities for the transfer of the functions of one organ to another.

Chapter III.

Of the Skin of a Plant, and the Parts connected therewith. Stomates, Hairs, Glands, Stings, Scurf, Prickles.

Over every part of a plant exposed to the air, except the stigma, is extended a skin, which serves at once to hold together and protect the parts beneath it. To the eye, even when assisted by powerful microscopes, it usually appears to be a thin transparent membrane, traversed by veins arranged with regularity in a netted manner. The meshes formed by the supposed veins are sometimes long hexagons (*fig.* 2, *a*); sometimes nearly regular

Fig. 2.



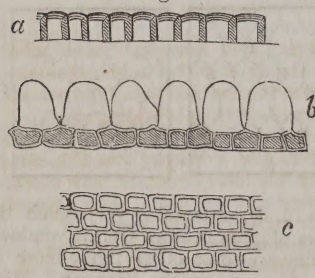
ones (2, *d*), resembling very much the panes of glass in some Gothic window; or they are some other figure more or less approaching the hexagon. More uncommonly they have an exceedingly wavy, curled outline, as in the common polypody (Polypodium vulgare) (2, *c*); and occasionally they are bounded by undulated parallel lines, as in the white lily (Lilium candidum) (2, *b*). In some instances the skin can be peeled off readily; in others, it adheres so firmly to the substance beneath it, that it cannot be separated.

But if it is examined with greater care and better glasses, it will be found to be by no means a simple membrane as it appeared at first sight. By making extremely thin slices of any part of a leaf for instance, perpendicular to its surface, and placing them in water under a powerful microscope, we find that this apparent membrane is in reality an excessively thin plate,

formed by the growing together of a vast multitude of little bladders or cells, squeezed flat, filled with air, and joined by their edges, which are what give the appearance of veins to the skin when it is peeled off.

The thickness, the form, and the number of layers of these little bladders are variable in different species; being apparently diversified according to the different circumstances under which species are exposed to the action of the atmosphere. Thus, in the white lily, the German iris, and the common bean, and perhaps the greater part of European plants, the bladders are in a single layer, and very thin-sided (3, *a*); in some succulent plants they are in three rows, one of which sometimes has the sides of the outer layer of cells partially separated from each other, as has been remarked by Adolphe Brongniart in Rochea falcata (3, *b*), when the surface of the plant acquires a warty appearance; in the *oleander* there are three or four layers of thick-sided cells (3, *c*).

Fig. 3.



The object of these differences in the structure of the skin will be explained when the nature of the functions of that part comes to be considered. For the present it is sufficient to state that they are principally intended to adapt a plant to the nature of the medium in which the leaves are developed. It is a general rule that leaves growing in the air have a skin, and that those growing constantly in water have none; and it being necessary that evaporation should be regulated in the former case, while in the latter no evaporation can take place, it is inferred that this duty devolves upon the cuticle, which in fact is admirably adapted to the purpose. In plants growing in the shade, or in damp situations, the cuticle is thin and soft, and readily permeable to water in a gaseous state, but in leaves exposed to much heat and dryness it becomes proportionably thick and hard; in succulent plants in which evaporation is hindered, in order that their dropsical condition may be insured, more layers than one of cuticle are often present; and finally, in the oleander, which has to bear the parched atmosphere of a Barbary summer, there is a triple coating of hard thick cuticle.

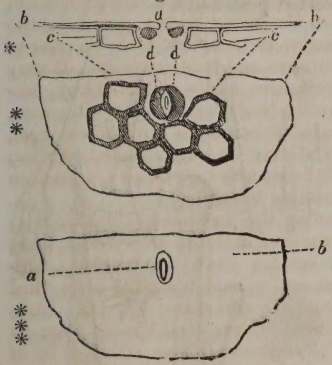
It appears probable, from the observations of Henslow and Adolphe Brongniart, that over the true skin is drawn an excessively thin pellicle which exhibits no appearance of organization, and which is perfectly homogeneous and continuous, except over the openings of the stomates. It is supposed that this pellicle, the use of which is unknown, may be what repels the water from the surface of some leaves, and causes it to separate into drops. It is difficult to detect it in the fresh leaf, in consequence not only of its being firmly glued to the subjacent cuticle, but also because of its thinness and transparency. It may be, however, easily detected, by macerating a leaf for a day or two in water, slightly impregnated with nitric acid, when it may be easily peeled off; for, notwithstanding its thinness, it is often remarkably tough.

Among the meshes of the skin may be remarked a number of oval spaces, much smaller than the meshes themselves, and placed upon the lines that indicate the juncture of the little bladders. These oval spaces (*fig.* 2) are the *stomates* above referred to of plants, and have a highly-curious structure. They are openings through the skin into the inside of a plant, and serve to establish a communication between the atmosphere and a complicated pneumatic apparatus which lies beneath the skin. They are constructed of two little oblong bladders, placed parallel with each other, and having a power of contraction or expansion, as circumstances may require: when at rest they are perfectly parallel, and, by pressing their sides together, close up the opening; when in action they curve away from each other in the middle, and thus leave the passage open.

The stomates sometimes seem bounded by a transparent limb, which is the portion of the pellicle between the blad-

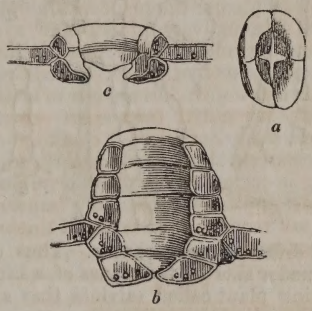
ders of the stomate and the contiguous bladders of the skin. When open they also appear as if two other little bladders interposed between the principal bladders and the opening; this is, however, a mere optical deception, caused by the thickness of the edge of the opening through the pellicle. The structure of these curious organs will be best understood from the following highly magnified figures. *Fig.* 4* represents a section of the skin of a plant perpendicular to the surface; *a* is the opening through the pellicle; *b* is the pellicle itself; *c, c,* are the bladders of the skin; *d, d,* are the two parallel bladders of the stomate. *Fig.* 4** represents the same parts seen from under the skin. *Fig.* 4*** shows the pellicle after the bladders of the skin and those of the stomate have been removed; the opening through the pellicle (*a*) being thus distinctly exposed to view.

Fig. 4.



It would be beside the object of this treatise to enter into an explanation of the many varieties of the stomate, especially as they are all formed upon a plan similar to that described; differing principally in the form of the constituent bladders; in their number, which is sometimes four, forming a square, or even five; and in their diameter, which, in the shortest direction, varies from the $\frac{1}{300}$ to the $\frac{1}{500}$ of an inch. But the structure of these parts in Marchantia has been ascertained by Mirbel to be so peculiar that it cannot be passed by in silence. In this imperfect plant there is no external pellicle, a slit in which forms the opening in the stomate; nor is the latter formed of a couple of bladders different in form and position from those of the skin. On the contrary, the stomate is a mere disunion and alteration in the adjustment of the bladders of the skin, with an addition to the under surface of four or five bladders which contract or expand, and thus enable the plant to respire. There is, however, very often an addition to the rim of the stomate of several tiers of bladders which rise perpendicularly from the surface. *Fig.* 5 represents some views of this kind of

Fig. 5.



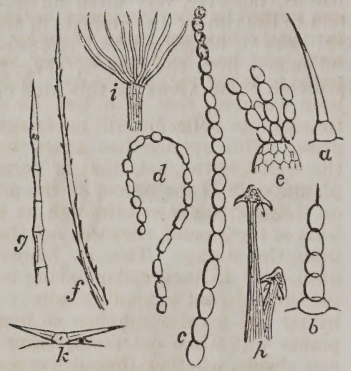
structure: *a* is a stomate seen from above the skin, with the four bladders that form the contracting organ, which Mirbel calls "the obturating ring;" *b* shows a section of a stomate of several tiers, and *c* of a simple one, the contracting bladders being, in both cases, the lowest; in *b* they are shown closed up, in *c* separated and open.

The name *breathing pore*, which is often applied to the stomates, sufficiently explains that these are considered organs of respiration; and there is every reason to believe that they are really of that nature. It will be seen hereafter that the life of plants is chiefly maintained by the introduction of carbonic acid into the leaves, and the expulsion of oxygen, which results from the decomposition of the carbonic acid. From the situation, form, and other circumstances connected with stomata, it seems certain that this important function is principally performed through their agency.

From the surface of the skin often arise little processes, which, in fact are mere expansions of it, to which we give the name of lymphatic hairs, or, more commonly, hairs only, from their resemblance in appearance to the down or hair of animals. These minute

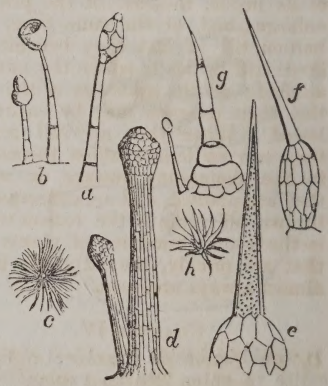
parts, which are so very fine and transparent that their structure can be ascertained only by the aid of a microscope, are usually short needle-like bodies lying nearly parallel with the surface of a plant (*fig.* 6, *a*). But occasionally they assume some remarkably different appearances. Thus on the under side of the leaves of a little floating plant called salvinia they are jointed cylinders ending abruptly in a minute bristle (*b*); in spiderwort (Tradescantia) they have exactly the appearance of the antennæ of some coleopterous insects (*c*); in the marvel of Peru (Mirabilis) they are composed of short cylindrical joints, separated by irregular contractions (*d*). Salvinia, on the upper side of its leaves, has them consisting of a few oval joints, all of equal size, and arising from a little projection of the surface (*e*); in hawkweed (Hieracium cymosum) they are covered with short teeth (*f*); in other plants with a number of fine bristles; in Xanthium spinosum they have the appearance of a bamboo in miniature, with the joints contracted in the middle (*g*); some Borageineous plants have them armed with barbs like the head of an Indian arrow, so that they cannot be withdrawn from such bodies as they may pierce (*h*); in a kind of lavatera (L. micans) they consist of a short stalk with a tuft of finer hairs springing from the top of it like the rays of a polype (*i*); and, finally, in malpighia and the Indigo plant, they are fixed by the middle, pointing in two opposite directions (*k*).

Fig. 6.



Glandular hairs, or *glands*, as they are more commonly designated, are formed upon the same plan as true hairs, and, like them, are generally too small to be examined with the naked eye; but they have a power of secreting various substances, such as resins, odoriferous essences, or other matter which the plants require to throw off; and to enable them to perform this office, they are provided with a little bag at their point, in which the secretion is collected before being discharged. Parts of this kind are found on plants, such as the sweetbriar rose, where they appear to the naked eye as rusty dots; in the chick pea (Cicer arietinum) they consist of a slender transparent stalk, terminated by a head full of little chambers (*fig.* 7, *a*); on the shell of the grey walnut (Juglans cinerea), they are terminated by cups, in which the secreting matter is collected before it is shed (*b*); in some crotons they spring up in clusters, and gradually thicken to the point; when very highly magnified, they appear like thick stiff bodies having the form of an inverted pestle (*d*).

Fig. 7.



Stings, the office of which would seem to be to keep off aggression by the pain they inflict when inserted into the skin of animals, are stiff, needle-like hairs, which arise from a thick swollen base full of chambers, in which the poison they secrete is collected and stored up. Some of the most characteristic forms are what occur in borage, where they consist of a bristle resembling the straight blade of a poniard (*fig.* 7, *e*); in the nettle, composed of one straight rigid hair bent at a very obtuse angle from the top of an obconical poison-chamber (*f*); and in the gourd, where the sting is jointed,

less rigid, and gradually passes into a conical chambered base (*g*).

Scurf (or scales, technically *lepides*, whence the adjective *lepidote*, for a scurfy surface) is found on the leaves of the pine apple, the sea buckthorn (Hippophäe rhamnoides), and many other plants. It appears to the naked eye as a mealy substance of a whitish or brownish colour; but, in reality, it consists of minute scales adhering by their middle, and formed by the growing together of a number of hairs which happen to spring from one common point. *Fig.* 7, *c* and *h*, show the appearance of the scurf of the wild oleaster (Elæagnus angustifolia), when seen under a microscope.

Prickles (aculei) are nothing but hairs of a larger growth; they are hard, horny, sharp-pointed, conical, and often hooked excrescences, which rise from the surface of the stem, from which they may be easily broken off. When young, they are small, soft, and green; as the surface of a stem distends in consequence of the expansion of its inside, the base of the prickles enlarges, and, at the same time, they harden, till at last they become the large stiff bodies to which the name is applied; on the branches of the rose this their progress may be easily followed. When they are full grown, they can no longer adjust themselves to the distending surface on which they are planted, and are consequently thrown off: this is the reason why it is the young branches of plants only that are prickly, the old stems being almost always unarmed.

Chapter IV.

Of the Trunk or Caudex; difference between Root and Stem.

The central part, or axis, of a plant, to which the leaves and flowers are attached, is technically called the *caudex*, to which the English word *trunk* seems equivalent, notwithstanding its being generally applied to the thick bole of a tree.

It consists of two portions; the ascending trunk, or *stem*, and the descending trunk, or *root*. Between these there is no absolute separation, each being an extension of the other in an opposite direction; the ascending trunk, or stem, having from its earliest existence an invincible tendency to grow upwards into the air and light, the descending trunk, or root, an equally irresistible determination to the earth away from light. (See Physiology.)

The one being thus an extension of the other, there is no definite organic separation between them; but their structure melts, as it were, completely together. Nevertheless, the imaginary line formed by the divergence of these two parts has the name of *collar* or *neck*, and has been erroneously supposed to be the seat of vitality. It has been asserted, that if a tree be cut through its collar, it will never again grow. This opinion has arisen from the well-known fact, that if certain plants, such as the beech, or the pine, or the oak, are sawed through at the level of the ground, they will not shoot from the stump. This is, however, owing, not to their collar having been cut through, but to another cause: for by far the greater number of woody plants will, when cut down, throw up new shoots, whether their collar is cut through or not; as, for example, the plum, the poplar, and the rose. It arises from a specific power, which varies in different species, of forming adventitious buds, from which alone new shoots can proceed.

The great differences between root and stem consist in their organic characters, rather than in their physiological peculiarities; for many stems burrow under ground, and many roots are emitted, and can only live, in light and air, the one performing, apparently, the office of the other. The common distinction, therefore, of a root being the under ground, and a stem the above ground, part of a plant, is not sufficiently exact for science.

The real distinctions between them are the following:—A stem is divided into a number of projections called *nodes*, equidistant, or which are either at regularly diminishing or increasing distances. To each node there is usually either a leaf, or a scale, which is an imperfectly-formed leaf, and at least one bud capable of growing into a branch, which will be covered in like manner with other nodes and buds, themselves capable of again shooting into branches. Consequently, as the ramifications of a stem can proceed only from the nodes thus symmetrically arranged, the branches must, of necessity, grow symmetrically also; and hence the pleasing appearance of the

head of a tree, even when stripped of leaves. Roots, on the contrary, have neither leaves, nodes, nor buds, nor anything which can be considered analogous to them. They have no provision made for a regular ramification, which indeed could not exist in a perpetually and unequally resisting medium like the earth, but they divide and subdivide as occasion requires, without the least disposition to assume a symmetrical form.

As branches are produced by buds alone, and as roots have no buds, it is obvious that if a tree is cut down to the collar, so that nothing remains but root, it can never branch again; and hence the opinion that the collar is the seat of life. But though roots have no buds under ordinary circumstances, yet they, and all other woody parts, have occasionally the power of forming what are called adventitious buds, under special circumstances. These adventitious buds sprout irregularly from various parts of the surface; and thus in certain species of plants renew the growth which had been temporarily arrested by the destruction of the stem. No one can tell why particular species have this power, and others not; but the fact is certain. The roots of the silver fir (Abies Picea), for instance, will live on the mountains of Switzerland for half a century after the stem is destroyed (*Dutrochet*), but will never sprout again; while, on the other hand, the root of the willow will form adventitious buds, and grow nearly as readily as the stem itself.

In their internal structure roots and stems are nearly alike, except that the former are rarely hollow, although many stems are; and that in the plants called *Exogens*, which have a pith in the centre of their stem, the root has no pith.

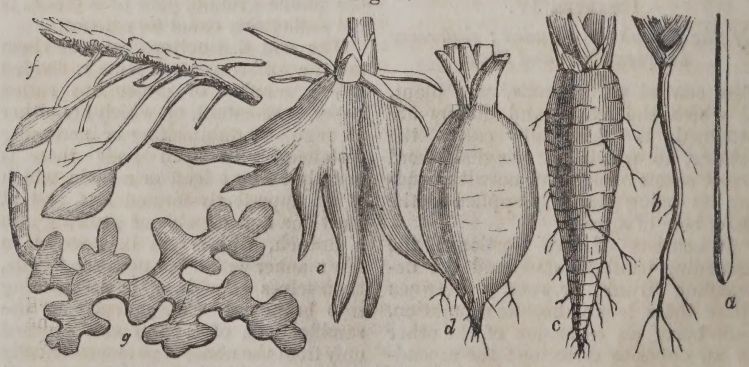
Chapter V.

Of True Roots and their Modifications; of Stems improperly called Roots.

Perhaps the most simple manner of understanding the structure of a root, limited as has been just explained, is to consider every form of that part a modification of a simple fibre.

A simple fibre consists of a cylinder, soft externally, and woody internally, ending in a blunt and succulent point (*fig.* 8, *a*), through which the fluid matter of the soil is sucked into the circulation. The aërial roots of such plants as ivy, dodder, and epiphytal orchideæ, are simple fibres altered according to the particular circumstances under which they are produced, and the modified functions they have to perform. In the dodder, for instance, they have to act as suckers as well as roots; and, accordingly, they are dilated at the end to enable them to perform that additional office. Suppose such fibres to increase in diameter principally by addition to their woody centre, and at the same time to lengthen and divide into a number of branches, each of which is like the primitive simple fibre, we shall then have a fibrous root of the commonest kind, such as that of all trees and shrubs, and of most herbaceous plants (*fig.* 8, *b*). Let it

Fig. 8.



increase much more in diameter than in length, and consist of no other ramifications than a few fibres protruded from the sides of a common centre, and such roots as those of the carrot, the radish, and the turnip, will be the re-

sult (*fig.* 8, *c* and *d*), the special figures of which will depend upon the degree in which the preponderance of growth is longitudinal, or transverse. It sometimes happens that some of the roots retain their fibrous state, while others, then called tubercles or fangs, become extremely fleshy and enlarged, as in fig wort (Ranunculus ficaria), in which the tubercles are thicker and blunter at the lower than the upper end; the roots of the dahlia and the orchis (*fig.* 8, *e*) are of a similar kind; or one portion of the root will be fibrous and the other tubercular, as in dropwort (Spiræa filipendula), (*fig.* 8, *f*). It is thought that such tubercles are intended by nature to contain a supply of food upon which the plant may exist when deprived of its usual nutriment from the earth or the atmosphere; there does not, however, appear to be sufficient evidence of the justice of this opinion. Sometimes a succulent root will ramify without increasing perceptibly in diameter, and consequently its ramifications will be all succulent and of equal thickness; such a root is that of the coral root (Corallorhiza), (*fig.* 8, *g*).

Whether or not the functions of all these sorts of roots are exactly the same is not known: their general office is, no doubt, firstly, to steady a plant in the soil in which it grows, so as to prevent its being blown about by wind; and, secondly, to suck from the earth the fluid matters which form vegetable food. The latter function may seem the more necessary of the two, but in reality the one is as important as the other; they always accompany each other, and when one is not provided for, the other appears unnecessary also. Thus, in sea-weeds, which are the only plants in which roots really seem to be unimportant, for they often grow while floating freely in the ocean, there can be no doubt that absorption of food takes place over all their surface; and it is always to be remembered that even plants like these are, at an early period of life, attached by a root, which may be supposed to perform at that time its ordinary double function. When roots are produced in the air, as in ivy, the vine in a hot damp stove, epiphytal orchideæ, and the like, it often happens that they have only the absorbing function to perform; but in such cases the business of fixing the plants steadily in their places is performed by other roots, which are emitted under or upon the surface of the ground.

In common language all kinds of underground stems are called roots; but it is necessary, both for the sake of exactness of language, and for practical purposes, to distinguish carefully between them; for while an underground stem is one of the means destined by nature for the multiplication of plants, a root will not act in that manner, except under certain special and very unusual circumstances. Neither do such stems ever appear to perform the office of roots; they seem to be chiefly intended to store up food for the use of animals. They are easily known from roots if the distinctions lately mentioned are attended to. The principal forms are the *rootstock*, the *cormus*, the *tuber*, and the *bulb*.

The *rootstock* (rhizoma in Latin) is a creeping or underground stem, which either has scales in the room of leaves, or is marked by the scars or remains of leaves that have either fallen off or withered. Of this nature are orris root and ginger; the former of which is the rootstock of a kind of iris (*fig.* 9, *b*), and the latter of the ginger plant. In the common polypody (*fig.* 9, *a*) it is a hairy body from which the leaves arise; and in the hare's foot fern (Trichomanes canariensis) it curves at its extremity like the paw of the animal after which it is named. What is commonly called a *creeping root* (soboles) (*fig.* 9, *c*) differs from the rootstock in nothing whatever except being more slender, and always subterranean, while the rootstock often lies prostrate on the surface of the ground. It has scales, which are the rudiments of leaves, at equal distances, and emits true roots from the nodes, where, also, are buds which are extremely active and ready to form new plants the instant they are placed in circumstances favourable to their development. Hence it is that couch grass, which has this sort of underground stem, if cut into pieces, forms a very vegetable hydra; for every joint is capable of growing into a new plant; and, consequently, by tearing an old plant to pieces a great number of new individuals is added to the soil, instead of one being destroyed. If it were a root, tearing it in pieces would probably destroy it. To this is also to be referred the *scaly root* of the old botanists (*fig.* 9, *d*), which is remarkable in Lathræa squamaria. It differs from the last in

nothing except that the scales with which it is covered are fleshy instead of being membranous, and that the buds at the nodes are much less active.

Fig. 9.

The *cormus*, for which we have no equivalent English word, is an extremely short subterranean stem, covered with several layers of dry withered scales, and usually having a roundish figure (*fig.* 9, *e*). It increases by the growth of the buds that exist at the axils of the scales, which, during their growth, feed upon the mother cormus, exhausting it of its soluble substance, and at last becoming cormi themselves when full grown. The root, as they say, of the crocus, the tulip, and the ixia, is a cormus.

The *tuber*, again, is a short, fleshy, underground stem, produced at the end of slender subterranean branches. Its surface is marked with scars, or covered with scales, from within which buds appear by which the species is to be multiplied. In the potato the underground branches are at first as slender as the roots among which they burrow; and are only to be known from them by their having scales upon their surface. But in time such a branch ceases to lengthen; its end then becomes swollen by the matter impelled into it, from the main stem not being able to proceed any further; it gradually increases in diameter, becomes more and more succulent, till, at last, a perfect tuber is formed, and the part of the branch not distended, decaying, separates from the parent plant as an independent individual. *Fig.* 10 shows the manner in which this takes place, and the appearance of the tubers at the different periods of their growth. When fully formed, a tuber is a fleshy body, on the surface of which are numerous depressions, each containing what a gardener calls an *eye*, which is in reality a bud, that, under favourable circumstances, will become a new plant. Hence such eyes or buds, along

Fig. 10.

with a portion of the tuber, forming together the *set*, are employed for the multiplication of a species, as in the potato. It generally happens that such eyes, like the buds on the branches of trees, do not develop the same year as they are formed, but pass the first season of their existence in gaining strength for their growth in the succeeding season. But if any circumstance should call them into action in the same season in which they are first created, a tuber will branch, and then assume an appearance very unlike its common state. This often happens to

the potato in long dry summers, when what are called clustered potatoes are generally produced. Such productions are excellent illustrations of the plan upon which tubers finally grow, and of the analogy that exists between them and branches, proving that what may appear to the superficial observer the obscure speculations of closet-philosophers, are in reality exact expositions of the plan of the creation.

The *bulb* (*fig.* 9, *f*) is a roundish body, consisting of scales packed closely one over the other, and emitting roots from its base, as in the onion. It is, in reality, an extremely short stem, covered with rudimentary leaves in the form of scales, and it differs in nothing from a bud, except that it either separates spontaneously from the part that bears it, as in the tiger lily, or it is a perfect plant in itself, as in the onion. Most commonly it lives underground; but in some lilies, alliums, and other plants, it is produced among the branches, leaves, or flowers. The tree onion is a plant in which bulbs are produced in the place of, and instead of, flowers; a singular circumstance which will be explained in another place. (*See* Chapter XXV.)

Chapter VI.

Of the Stem, and its external modifications: Spines; Tendrils.

Although the stem is, even more than the root, subject to modifications of form, yet its names are far less numerous. In its commonest state it rises erect from the earth, dividing into many branches: in herbs succulent and perishable; in shrubs and trees woody, and clothed with a thick and rugged bark. But from this state, which may be considered normal, it departs in a great variety of ways. In palms and similar trees of tropical countries it forms a cylinder, bearing a tuft of leaves at its point. In other plants it is little more than a delicate thread lying prostrate on the earth, as in the runner of the strawberry. In some species it takes a twining direction, following the sun in his course; and when of a woody structure, enfolding the largest trees with its gigantic coils. In the Museum at Paris there is a specimen of a palm-tree so surrounded by a monstrous twiner, the coils of which have grown to each other, as to be enclosed in a kind of vegetable sheath. Occasionally in the forests of tropical countries the stems of woody plants at first rise straight into the air; but not becoming sufficiently solid to support their growing weight, they gradually fall prostrate among the trees that surround them, and obstruct the traveller like cables drawn across his path. In most plants the stem is solid: in grasses and umbelliferous plants it is hollow; in a few species its bark is expanded longitudinally into green and leafy wings. These are the commonest forms we meet with in the stems of plants. Others there are which are yet more remarkable. In a kind of cabbage, called Kohlrabi, the stem shortens and distends till it acquires a globular form like that of a turnip. In the tortoise plant of the Cape of Good Hope, it is a roundish knob of considerable size, the bark of which is rent into deep fissures, separating spaces having the appearance of the scales on the back of a tortoise. Many tropical orchideous plants have a short conical stem named a pseudo-bulb, terminated by one or two leaves, and arising from a prostrate rootstock. In Stapelias (*fig.* 11, *a*), and some other South African plants, the stem becomes gouty, distorted, and succulent, bearing soft projections instead of leaves; and, finally, in the Cactus tribe it is sometimes flat and divided into a number of leafy limbs (*fig.* 11, *c*), or globular and deeply furrowed with sharp projecting ribs (*b*), or angular and erect, often rising into the air like a vegetable column.

Fig. 11.

Such are the most remarkable of the forms which occur among stems properly so called. Branches, in woody

plants, sometimes suddenly lose the power of lengthening, harden and sharpen at their points, and thus form spines, as in the sloe and hawthorn; or they lose their woody character, produce none but starved and scale-like leaves, becoming weak and curling up at their points, so as to form the tendrils by which some plants, such as the vine, contrive to climb among their neighbours. In the duck-weed, and all the Lichen tribe, the stem is a flat horizontal expansion, destitute of woodiness, and apparently amalgamated with the leaves.

Chapter VII.

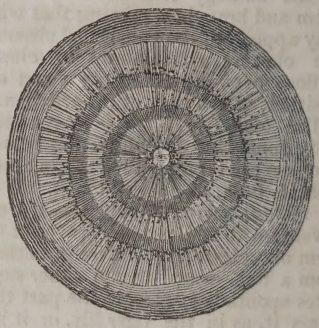
Of the Stem, and its internal modifications Exogens, Endogens, Acrogens.

In their internal structure stems are apparently constructed upon several different plans: in the bamboo they are hollow with transverse partitions; in the cane they are solid, and of an uniform density; in the oak they are hardest in the centre; in the cocoa-nut they are softest in the centre; in many climbers they have an uniform density, and appear pierced with multitudes of cylindrical channels parallel with the bark. In ferns the wood has a singularly twisted appearance; and, finally, in many herbaceous plants, it seems to consist of a mass of succulent substance, with a few fibres mixed among it. But it has been ascertained that all these variations are to be reduced to three primary forms, viz.: Exogens, or those which have their woody system separated from the cellular and arranged in concentric zones; Endogens, in which the woody and cellular systems are mixed together into a confused mass; and Acrogens, which consist of a cylinder growing at its point only, and never augmenting in thickness after it once is formed. We must examine each of these separately.

A stem which is formed upon the *Exogenous* plan, when cut through transversely, exhibits a central *pith*, surrounded by one or more circles of *wood*, on the outside of which is a ring of *bark*, which is connected with the pith by a number of lines passing through the wood called *medullary processes*. A branch of hazel, beech, or oak represents this structure very distinctly.

In plants whose stems exist only for a single year, there is but one circle of wood; and if such stems are very succulent, it may even be difficult to ascertain the presence of wood at all.

Fig. 12.



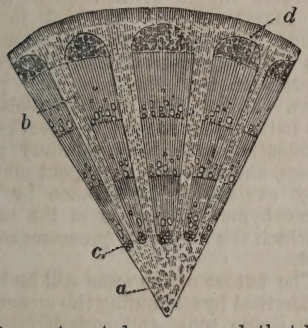
But it will always be found, upon close inspection, that some trace of woody matter exists arranged in a definite manner between the pith and the bark, separated perhaps by medullary rays, which are much thicker than the contiguous plates of wood, and which on that account tend to conceal the real structure. Such is the case in the stems and roots of many common herbaceous plants, and of cacti and similar succulent plants. Passing by, therefore, cases of this kind, the analogy of which with the exogenous structure a little consideration will serve to make apparent, let us examine in detail the exact structure of the various parts that make an exogenous stem.

The *pith* (*fig.* 13, *a*) is a spongy column which extends from the collar, where it usually ceases, to the extremities of the branches. When young it is succulent; when old it becomes dry. Usually it is solid; but in umbelliferous plants it is soon torn to pieces by the rapid distention of the woody cylinder that surrounds it, and its place is occupied by an empty tube, to the sides of which it adheres in fragments. In the walnut it is divided into a number of narrow chambers, placed over each other with great regularity. It is united with the *medullary* rays or plates, or *processes*, as they are more correctly called, by an infinite multitude of points arising from over all its surface. When young it is green and succulent, and at that time only is to be considered a living organ; its office, at that time, is to supply proper

food to the young buds which are in communication with it, until those parts, by their subsequent growth, become capable of obtaining it from other sources. After this business has been fulfilled, it dries up, and dies.

The *medullary processes* (*fig.* 13, *b*), which thus arise from the pith, of which in fact they are mere extensions, pass straight into the bark, cutting the intervening wood into a number of wedges, the broad end of which is next the outside of the stem. They are composed of the same spongy substance as the pith, squeezed in between the wedges of wood, and consequently very much compressed. In trees, the medullary plates are usually extremely thin; in succulent plants, or annual stems, they are more frequently of considerable thickness.

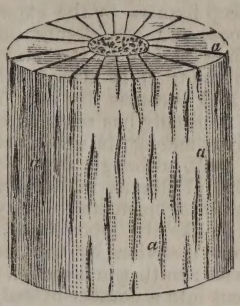
Fig. 13.



It must not be supposed, that because the medullary processes are spoken of as plates connecting the pith with the bark they are therefore of very considerable depth, or that they really divide the wood into distinct wedges. These terms are merely used to express the appearance of the parts in a transverse section of a piece of exogenous wood; in reality, the medullary plates are in general thin, and by no means deep processes, piercing the mass of wood as is seen at *fig.* 14, which represents a portion of a cylinder of wood stripped of bark, with the mouths of the medullary processes seen on the outside of the wood at *a*, *a*.

The office of these processes is very important. They are the great means of communication between the circumference and the centre of a stem, and are what enable the fluid matter, which passes down the bark, to reach the wood which is next the pith. To qualify them for performing this office the better, their component parts are placed with their longer diameter perpendicular to the bark; a position which is the most favourable which vegetable tissue could assume under such circumstances, to perform a function in which capillary attraction is the great moving power. When examined under a microscope, the component parts of the medullary processes resemble bricks placed across the fibres of the wood, and the processes themselves may be not unaptly compared to low walls stretching from the bark to the pith. This will be more particularly explained in the chapter on the elementary organs.

Fig. 14.



The *bark* (*fig.* 13, *d*) consists of two distinct parts; namely, of an external layer of a spongy substance which is usually green, and of an interior layer of fibrous matter which touches the wood, and at one time appears to be organically combined with the wedges of the latter. Of these layers, the external is called the cortical integument, and the interior the *liber*. Every year an addition of new *liber* is made, in the form of a concentric zone, within that of the preceding year; and consequently the bark would be marked with as many concentric circles of liber as it is years old; but as the wood that forms beneath the bark is perpetually straining the latter transversely, and so disturbing the relative position of its component parts, it happens that, in point of fact, the bark soon loses all trace of the concentric annual zones of liber, and becomes a confused mass of fibrous and spongy matter mixed together, its lining being the only part in which the liber remains undisturbed. The cortical integument, which has been justly called by Dutrochet an external pith, is sometimes soft and extremely thick, as in

the cork-tree, where it furnishes that material which proves so useful to the wine-merchant. In trees, however, it is more frequently hard and gritty, rent into deep fissures by the expansion of the wood, and mouldering under the corroding action of the atmosphere. When young it is always filled with fluid, and becomes dry only from old age. It usually has some fibrous matter mixed among its substance. The *liber* itself, although described as a cylinder of fibrous matter lining the cortical integument and overlaying the wood, is, like the wood itself, pierced in every direction by the medullary processes; so that in a section it seems to be cut into a number of wedges corresponding with the wedges of wood (*fig.* 13). Although it appears, when young, to be organically connected with the wood, yet it always separates freely when an attempt is made to tear it off, and, when full grown, the separation is made spontaneously. In some plants it is remarkable for its susceptibility of being stripped into a very considerable number of thin layers, which, in consequence of their fibrous structure, are tough enough to be employed for useful purposes. The liber of trees, before the invention of paper or parchment, was stripped into layers, flattened and cemented into leaves, upon which books were written, whence its name. In the present day, the liber of the lime tree is an important object with the Russians, who manufacture from it the coarse mats which bear their name; but the most curious instance is in the lace bark of Jamaica, in which the layers of liber are very numerous, quite white, extremely fine, and when stretched out, open into a kind of delicate net-work resembling lace. It must not, however, be supposed that nothing is liber except that young fibrous lining of the bark which we find in stripping the latter from a tree: on the contrary, it may happen that bark consists of liber on the outside as well as inside; because as bark is constantly wearing away externally, and the interior parts are perpetually pushed outwards, a time must come when the first-formed liber will reach the surface; and during the remainder of the life of such a plant the bark of its trunk must consist of liber at the very surface; such liber is, however, dead, like all the parts in contact with it. That the part of the bark which originally was internal does in time arrive at the outside of a stem is easily proved by inserting a wire into the bark of an exogen through the young and innermost liber; in a few years the wire will reach the outside, and be thrown off.

It is through the bark exclusively that the returning fluid of a plant descends to the root; and it is in this part that many secretions are chiefly stored up: for it is a remarkable fact, that in plants secreting substances of different physical properties, while one kind is freely conveyed to the central wood from the bark through the medullary processes, another part seems scarcely capable of following such a direction. Gum, for example, which so abounds in the bark of a cherry or a plum-tree, reaches the central wood in very small quantity, while a considerable supply of astringent matter passes off from the bark to the wood. To what cause this is owing has not been ascertained. It is not improbable that the gum may pass down through the woody vessels of the bark, which are not in direct communication with the medullary processes, and that the astringent matter may exclusively pass down by the parenchymatous portion of the bark, of which the medullary processes are a part.

The nature of the *wood* will be best understood by examining the structure of a single zone, and considering all the other zones subsequently formed to be merely repetitions of it. Next the pith is placed what is called the *medullary sheath* (*fig.* 13, *c*), which is a stratum of air-vessels forming a sort of casing to the pith, but interrupted perpetually by the medullary processes which pass through it. On the outside of the medullary sheath is a mixture of large vessels and fibrous matter, the former predominating; and on the outside of all, finishing the concentric zone, is a deep mass of fibrous matter, with a number of small vessels intermixed: in all the other zones exactly the same structure is repeated as long as the plant continues to grow; so that the trunk of the largest exogenous tree is a mere repetition of woody or cortical zones, the youngest of the latter being formed withinside the older, and the youngest of the former outside the older. Occasionally a small quantity of the cellular substance of the

medullary processes is interposed between the zones, as in Urtica gigas; but more frequently they touch each other without any such intervention. In some plants, scarcely any vessels are to be distinguished among the fibrous matter of the wood, or there is but little apparent distinction between the different zones; but, in the main, the structure just described is that of exogens in general.

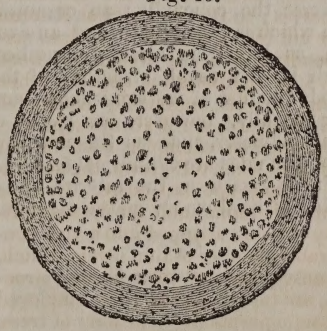
Perhaps it would be more correct to say that the woody matter is plunged into a mass of spongy or cellular substance, and arranges itself methodically in zones, than to use the language that has been hitherto employed; but this is merely a speculative point.

The anomalies which are met with in plants having this structure, however different from the normal state they may at first appear, are all easily to be reconciled with what we have described as the type of exogenous formation. Thus, in bauhinias the zones of wood are excessively irregular and unequal; in the water vine of India the medullary processes are very deep and thick, and filled with vessels; in arborescent birthworts, there is but one zone of wood, whatever the age of the stem. Finally, in calycanthus there are four centres of growth having each its own concentric zones lying in the bark at equal distances, and on the outside of the principal mass of wood. For these and other unusual kinds of structure, see *Lindley's Introduction to Botany*, &c.

Like the roots, wood has two distinct offices to perform. In the first place, it gives plants that solidity and toughness which enables them to stand erect in the air, without being destroyed by winds, or crushed by their own weight; a position which it is indispensable that the greater part of the vegetable kingdom should occupy, whether for the due performance of their own vital actions, or for rendering the earth habitable by man. In the second place, it is through the wood exclusively that the crude sap rises from the roots towards the leaves, for the better performing of which it has a simple and yet highly elaborate apparatus of tubes and vessels. The latter, which, when young, serve as conduits for fluid, become, when old, receptacles of the peculiar secretions of trees. In their young state they are nearly colourless, and form a pale mass, which we call *alburnum* or sap-wood; when old and filled with secreted matter, they become dark brown, or green, or even nearly black, in different species, and then are *heart-wood* or *duramen*. Being in this state clogged up by the matter that is lodged in them by the medullary processes, they are unfit for the conveyance of fluid, which accordingly takes place principally in the new tubes and vessels which remain open.

Endogenous stems apparently differ very much from these, for they have neither pith, nor medullary processes,

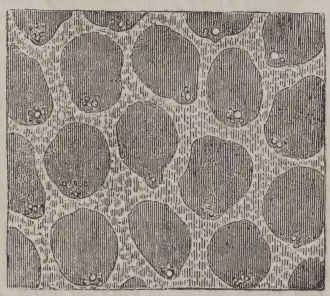
Fig. 15.



nor bark, nor wood properly so called; but they consist of a confused mass of bundles of woody substance lying in the midst of a spongy matter. In a palm we find an external cortical integument without liber; the bundles of woody matter so arranged as to be much more numerous and compact at the circumference than towards the centre. In the cane, which is another kind of palm, the woody bundles are distributed equally throughout the whole substance. In the asparagus, the aloe, and other soft-stemmed species, the woody bundles are not only equally distributed, but are so soft as to be scarcely recognised for the same thing as the hard fibres of a palm stem. Now, if we compare a stem of this sort with that of an exogen, we are, at first sight, unable to discover any analogy between them; but upon a more careful inspection, it will be discovered that the principal organic difference consists in the woody matter of exogens being arranged in wedge-shaped parcels, plunged into the spongy substance of the stem, and disposed in annual zones; while in endogens the woody matter is neither collected into

wedge shaped parcels, nor arranged in annual concentric zones, but is broken up into fibrous bundles plunged without order into the spongy mass. The correctness of this view of their analogy will be better shown, if the anatomical structure of a woody bundle of an endogen be contrasted with that of the woody wedge of an exogen. The woody bundle of an endogenous plant, if examined under a microscope, is found to be concavo-convex, with its convexity turned towards the outside of the stem. The convex part uniformly consists of compact woody matter, while vessels of various kinds traverse the concavity; an organization which is precisely that of an exogen, as has been already described. Such is the usual structure of the woody bundles of an exogenous stem. Occasionally, however, in stems of small diameter, such as the cane, the woody bundles are cylindrical (*fig.* 16), with the vessels in the interior, and a casing of hard woody matter all round

Fig. 16.

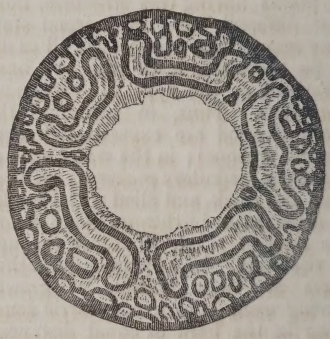


them. Another and a more remarkable deviation from the general structure of endogens is met with in grasses, the stems of which are generally hollow between the nodes where the sides are connected by transverse partitions; but the arrangement of matter in the solid shell being entirely that of palms, grasses cannot be considered to offer an exception to the law of endogenous structure. It is unnecessary to add that where stems are of very small size, corresponding modifications in the arrangement of the parts are to be expected; such, for instance, as the reduction of the woody matter to one single woody bundle, surrounded by a thin coating of cellular substance.

Arborescent Endogens being exclusively natives of hot countries, where Europeans have seldom an opportunity of examining minutely into matters which require the long and patient investigation of resident observers, nothing certain is known of the channels through which the ascending and descending currents pass in their stems. From analogy, it is presumed that the sap rises by the woody bundles, and descends through the soft spongy matter, but this is entirely conjectural.

Acrogens are totally different in their organization from both the last. In ferns, which are most remarkable both for their size and singularity of structure, the stem (*fig.* 17) is a cylinder, usually hollow; if solid, having the

Fig. 17.



centre filled with a spongy substance, destitute of bark, with neither woody bundles nor woody wedges interspersed among the general substance of the stem. The shell of this cylinder, which answers to the woody part o other plants, is composed of excessively hard plates, folded upon themselves in such a manner that a section of them represents a number of sinuous lines doubling about among spongy matter. These never increase in thickness, number, or quantity, after being once formed; but they seem as if they were, as in all probability they are, mere prolongations of the woody matter lying inside the footstalks of the leaves; whereas exogens increase by addition to the outside of their wood, and endogens, by addition, to the inside of their stem, whence their respective names have been formed. Acrogens seem to have little or no power of increase in diameter, but simply to lengthen by continual extension of their points; their name has been contrived from this circumstance.

To these principal variations of the mode of growth in the stems of plants should, perhaps, be added a fourth form, of which little notice has hitherto been taken by botanists. This, which might be called the *centrifugal*, occurs in fungi, lichens, and the lower orders of plants; and consists of a fleshy or spongy mass, or of filamentous processes radiating from a common centre.

In many respects this is the same as the Acrogenous, of which, indeed, it may be considered a mere variety; for its ramifications do not increase much in thickness after they once are formed; it nevertheless deserves to be specially explained. In an obscure plant called Marchantia, Mirbel found that a little thin green plate was first formed by the action of the reproductive grains or seedlets; and that it was from the edges of this plate, when once fully formed, that all the succeeding expansions took place, as from a common centre, but always upon the same plane; so that in such plants the central part is the oldest, and the circumference the youngest. This is very apparent in lichens, which, when very large, are always dead in the centre, while they continue to go on growing from every part of their margin. Fairy rings are an exemplification of the same thing in fungi; these appearances are external indications of the centrifugal growth of the subterranean stems of certain agarics, which originally spring from a common point, continually spreading outwards upon the same plane, the central or first-formed parts perishing as the circumferential or latest-formed parts develope.

Chapter VIII.

Of Leaf-buds.

From little conical projections from the stem, which are at first of an uniform substance, but which are eventually covered by minute scales very regularly and closely arranged one over the other, the branches of a plant are produced; and without them, no other increase in bulk can take place besides an expansion in all directions such as characterizes the centrifugal mode of growth, and such as we find in fungi. In other words, they may be said to be growing points, covered with rudimentary leaves, for their protection, and to consist of a highly-excitable mass of parenchymatous matter originating in the pith, and possessing a special power of extension in length.

Such conical projections are called *leaf-buds*. They are normally (that is, under common circumstances) formed exclusively at the nodes and from the axil of a leaf. Even in the very infancy of a plant, while it is yet in embryo, they appear at the axil of the seed-leaves or cotyledons, when they are called the *plumule;* and at every successive stage of growth they are ultimately produced as the leaves expand.

Although they appear to be mere projections of the surface, yet in reality they are not so; but are intimately connected, for most important reasons, with the very centre of the stem. In exogens they universally originate either from the termination of the pith, or at the outer end or mouth of one of the medullary processes, of which they are, in fact, an external prolongation, and by which they are, consequently, in direct communication with the pith. In endogens, their origin has not been traced with the same exactness; but there seems no reason to doubt their origi nating in the pulpy substance which in these plants corresponds with the medullary system of exogens.

Being axillary to leaves, they are consequently confined to the nodes, of which they are, therefore, an indication, as they must also indirectly be of the leaves when those organs have fallen off. Usually they grow singly; but in some plants, as in the peach-tree, they appear in greater numbers.

They most commonly lengthen out into branches; but sometimes if anything tends to interrupt or stunt their growth, they exchange their power of lengthening for that of hardening and sharpening at the point, and thus become *spines* or *thorns*, which are consequently very different from prickles. This may be distinctly ascertained by examining the wild orange, or which will do as well, the common hawthorn, in which the branches will be found in all their different stages of alteration into spines.

The analogy of a spine of this kind with other parts is not generally explained in elementary works. Yet, if the nature of a bud is correctly understood, such a structure is by no means difficult of explanation. It has already been stated that the leaf-bud

is a growing point capable of longitudinal extension. Usually it produces leaves as it lengthens, and if those organs are green and at regular appreciable distances, it forms a branch, but if they are coloured, placed close together, and differently shaped from leaves, it forms a flower; it is only when the lengthened point is absolutely naked, hard, and sharp, as in the wild orange, that it is a spine. There are several unsuspected analogies with this: one of which is the spadix of an arum, the succulent, blunt, subcylindrical, naked end of which is an undoubted form of the growing point; another is the succulent receptacle of a strawberry; a third the curious chambered disc of Nelumbium.

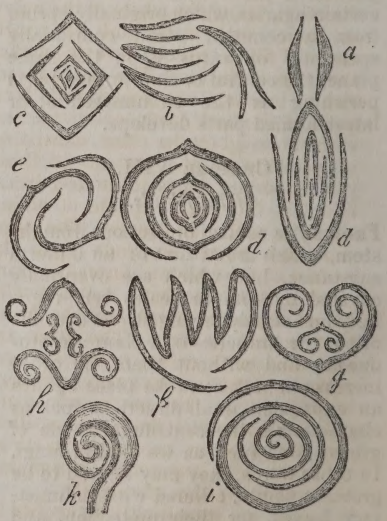
When leaf-buds appear from any other part of the stem than the node, they are considered altogether irregular in their position, and are called *adventitious*. Such, for instance, are those which often arise from the roots. Botanists are unacquainted with the cause of parts which do not habitually produce those organs occasionally giving rise to them; but it is certain that any of the pulpy or parenchymatous parts may, under particular circumstances, produce leaf-buds. Thus they are of constant occurrence at the margin of the leaves in the plant called bryophyllum; they are generated in abundance by the roots of the Cydonia japonica, and many others; and they have even been seen by Mr. Turpin sprouting from the surface of the leaves of a kind of Star of Bethlehem—not to mention other instances.

These facts explain many circumstances that would be otherwise unintelligible in the growth of plants, such as the power that roots possess of propagating an individual, and the appearance of branches from places where they would not otherwise be expected, of which we shall treat fully under Physiology. They also throw great light upon the origin of seeds.

It is sufficient to mention in this place, that the office of leaf-buds is to propagate individuals, seeds having no power to do more than increase a species; so that if a variety of any species is to be multiplied, that can only be done by aid of the leaf-buds, as is exemplified in the common gardening operations of *budding* and *grafting*, and *striking* from eyes. They, and the leaves together, are also the origin of the woody part of all plants, which first appears when the *seed-leaves* or *cotyledons*, and the *seed-bud* or *plumule*, begin to act, and which is afterwards augmented in proportion to the development of leaves and leaf-buds.

After the leaf-buds have begun to grow, and have been covered with scales for their protection, they form, beneath the scales, a number of rudimentary leaves, which are ready to unfold and augment in size with rapidity as soon as the branch is called into action. Nothing can be more curious than the manner in which these little rudiments of leaves are packed up within the bud, so as to occupy the smallest possible quantity of room; or more remarkable than the exactness with which the particular mode of folding which may be peculiar to a given species, is observed in every bud of every individual. There is no uncertainty in the disposition of these minute parts, no confusion in the arrangement, nor anything left to chance; but every plait is so evidently ordered by some great and unvarying superintendent Power, that the manner in which the young leaves are folded up has been adopted for purposes of systematic arrangement under the name of *vernation*, or *gemmation*, or *præfoliation*.

Fig. 18.



A chapter might be written upon the many different ways in which verna-

tion takes place; but we must here confine ourselves to an indication of the most remarkable, trusting to the figures which represent the plan of transverse sections of different leaf-buds, for an explanation of the terms. The principal forms of vernation are, 1st, the *appressed* (*fig.* 18, *a*), as in misletoe; 2nd, *conduplicate* (*b*), as in the rose; 3d, *imbricate* (*c*), as in the lilac; 4th, *equitant* (*d*), as in the iris; 5th, *obvolute* (*e*), as in the sage; 6th, *plaited* (*f*), as in the vine; 7th, *involute* (*g*), as in the violet; 8th, *revolute* (*h*), as in the willow; 9th, *convolute*, or *supervolute* (*i*), as in the apricot; and 10th, *circinate* (*k*), as in sundew (drosera).

Chapter IX.

Of Leaves, their position and external structure.

The stem is clothed with what are collectively called its appendages, or appendages of the axis, consisting of leaves and their modifications, and of flowers with their parts. The former, taken with the stem itself, are called *organs of vegetation* or *nutrition*; the latter of *fructification* or *reproduction*.

Leaves are usually those expansions of the bark into which slender processes of the wood and fibre insinuate themselves, and within which, after shooting beyond the surface of the stem, they expand and branch in every direction, filling the whole of the pulpy substance with a network of tough and stiff fibres, which serve to sustain the mass of the leaf. The leaf is therefore in intimate connexion with both parts of the bark on the one hand, and with the wood on the other, consisting of portions of the systems of these two important parts intimately intermingled, but each capable of acting singly as well as in concert. The pulpy substance which expands from the surface of the bark and forms the principal part of the leaf, is technically named the *parenchyma*, and the fibres that sustain it *veins*. The latter are also frequently called *nerves* or *nervures* in botanical language, although improperly, for they are merely channels through which fluids are impelled, and they have no connexion, as far as we know, with any action resembling the nervous system of animals.

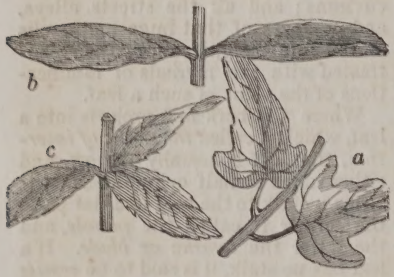
Leaves are exceedingly diversified in form, in the figure of their outline, in their position with respect to each other, in their texture, and especially in their degree of development; some leaves being nothing more than minute scales, into which the fibrous system can hardly penetrate, and others being of a size which, to those accustomed only to contemplate the foliage of European plants, must appear almost fabulous. The leaves of the bujoor palm of India (corypha elata) often measure thirty feet in circumference, and have a stalk to support them twelve feet long; so that if placed on the ground, one of these enormous leaves would be four times as high as a tall man. There is no machine of human invention, however extensive and complicated, which can for a moment be compared with such a natural apparatus as this for wonderfully elaborate mechanism. Its digesting cells are infinitely more numerous than all the houses of London and its environs; and all the streets, alleys, and passages of that huge metropolis shrink into insignificance when contrasted with the myriads of ramifications of the veins of such a leaf.

Where the bark first projects into a leaf, which is called *the point of insertion*, the leaf is usually narrow, and either round or half cylindrical, and it forms a stalk to the thin and flat part; the former is called the *petiole*, and the latter the *lamina* or *blade*. If a leaf has no stalk, it is said to be *sessile* upon the stem. The stalk of a leaf is therefore merely the channel of communication between the leaf and the stem, and may be supposed to be produced by the woody matter when it first quits the stem to form a leaf, before it begins to ramify; and it in fact consists of one or more bundles of woody matter surrounded with cortical integument. In many plants, such as grasses and sedges, it is thin, and organized exactly like the blade itself; in some plants it appears to exist without any blade, and consequently to be of itself capable of performing all the functions of a leaf, as in some strelitzias, in what are called leafless acacias, and possibly in the majority of endogens. Although, therefore, apparently a distinct organ in many cases, sometimes being even jointed with the blade, the stalk is in fact nothing but the lower portion of the leaf; and hence in all reasoning concerning identity of structure, or of

origin of parts, the stalk and blade are to be considered one and the same organ, and need not be specially distinguished. The importance of this axiom will appear hereafter.

If the branch of any plant be taken for examination, it will always be found that the leaves are arranged in some particular order; and that all other branches of the same individual, or of the same species, have the leaves arranged in the same order, so that the largest tree is merely a mass of branches, all of which are essentially the same. In all cases they arise from a node, and form one or more leaf-buds in their axil. In position, with relation to one another, they are either placed *alternately* one above the other (*fig.* 19, *a*), seemingly on opposite sides of the stem, or they arise from opposite sides of the stem at the same level,

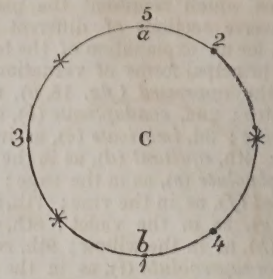
Fig. 19.



when they are called *opposite* (*b*), if growing in pairs, or *whorled* or *verticillate* (*c*), if there are several in opposition.

It is, however, especially to be remarked, that in alternate leaves, one leaf is not exactly opposite the other at a higher level on the stem, although it seems to be so, but it is placed a little to the right or left of what would be exactly a central point, and the leaf which succeeds is in like manner a little out of opposition, and so on; thus several leaves may be produced before another shall be exactly opposite to that from which the observer started. This will be clearer if we project the places of the leaves upon a circle. Let *a b*, in the circle C, be two opposite points: *b* we will suppose is the origin of a leaf, number 1; the second may appear at 2; the third at 3; the fourth at 4; and it would not be till the fifth leaf was produced that *a*, the point opposite to *b*, would be exactly touched. Now, as the wood of a branch is formed by the action of

Fig. 20.

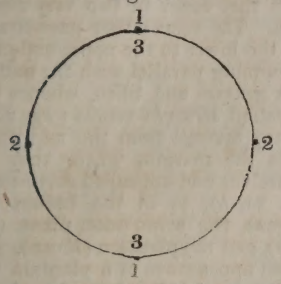


leaves, as will be hereafter shown, this is a beautiful provision of nature to insure the exact symmetry of the branches: for, although if the branch represented by the circle C consisted of but five leaves, as placed upon the diagram, more wood would be formed from 2 to 5, and from 1 to 4, than from 1 to 3, or from 3 to 5, or from 2 to 4, yet if only three more leaves were developed, those three would, upon the same principle of arrangement, be stationed in the wider spaces at *, and thus would fill up the very parts where they would be required to form wood to complete the circularity of the branch. This law is adhered to in a most remarkable manner in all leaf-bearing plants; and appears to be in reality owing to leaves being constantly disposed in a spiral manner from the base to the apex of a branch. This order is not, indeed, obvious in branches, when the leaves are very far asunder, although even in such cases it may be detected by drawing a line from the base of the lowest leaf to that of the one above it, and so proceeding until the bases of all the leaves on the branch are connected. But when leaves are small and arranged very compactly, as on the branch of an araucaria pine, or on the cone of any fir or pine, the spiral disposition is at once manifest; and in the trees called pandanus by botanists, the spiral arrangement is so very remarkable over all the branches, that they are hence called by the English screw pines.

It is not in alternate-leaved plants alone that this order of leafing is observed; even in those with opposite and verticillate leaves it takes place, only in a somewhat different manner. In opposite-leaved plants the pairs

generally *decussate*, that is, cross each other at right angles; so that the corresponding leaves of each alternate pair are placed exactly one over the other, as at *fig.* 21, where 1, 1, repre-

Fig. 21.

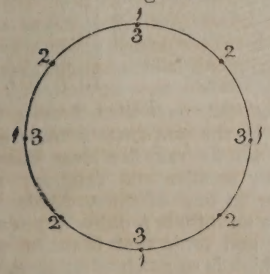


sent the places of the first pair of leaves; 2, 2, those of the second pair, and 3, 3, those of the third pair, which corresponds with 1, 1. The consequence of this is, that the young branches of opposite-leaved plants are usually more or less four-cornered, instead of circular

Whorled-leaved plants have their leaves placed in precisely the same manner as the last; that is, each whorl crosses that which preceded it, as in *fig.* 22, where the first whorl is represented by 1; the second by 2; and the third by 3.

That leaves such as those last described should also be reconcileable with the notion of a spiral arrangement seems at first sight improbable. But if they are studied with care, certain facts will be discovered which not only tend to render such an opinion probable, but almost to demonstrate

Fig. 22.



its truth, and that in reality all modes of arrangement in leaves are reducible to the theory of a spiral. In all considerations of this nature we must study intermediate forms and structure, and not confine ourselves to extreme cases; and in seeking to discover the analogy between the opposite and alternate forms of leafing, we must not confine ourselves to branches where leaves are invariably one or the other, but take those in which there exists a tendency to vary. Thus, in the rhododendron ponticum some leaves are opposite, some alternate. In this case we find that the leaves become opposite where the internode, or space between two leaves, is not developed; and that when it is developed, the leaves are alternate. Again, in many heaths, whose leaves are habitually whorled, or in honeysuckles, in which they are opposite, it is found, that if anything disturbs this arrangement, such as preternaturally rapid growth, the whorls or pairs separate, and the leaves become alternate, acquiring a spiral order. Again, if branches, the leaves of which, under common circumstances, are alternate, become unnaturally contracted, as in the majority of what are called stemless plants, the strawberry, for instance, the leaves, which would, under different circumstances, have been alternate, become opposite or whorled. Hence it is inferred, that when branches grow in an uninterrupted manner, their leaves are always alternate; that when they are alternately stopped in their growth, as if subject to a sort of oscillation of development, they become opposite; and that when this stoppage takes place, till three or more leaves are produced before the growth of the branch is continued, they become whorled. No cause can be assigned for such a growth and stoppage of growth in branches; but it appears to be one of those specific vital phenomena, with a knowledge of the existence of which the human mind must remain satisfied.

Chapter X.

Of Leaves continued; their usual modifications of Form.

In its usual or regular state, a leaf is a thin expansion with one surface turned towards the heavens and the other towards the earth. In this state it is liable to very numerous varieties of form, by which botanists distinguish species from each other, but into all the details of which this is not the place to enter. The greater part of these are designated by terms

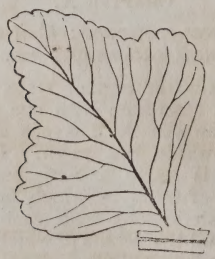
which are either used in their ordinary acceptation, or, being applied to other parts as well as leaves, enter into the list of names which will hereafter be explained in descriptive botany. We shall confine ourselves to those forms which are peculiarly characteristic of leaves.

It is the opinion of botanists that the most remarkable of the forms we meet with in leaves are owing to the peculiar manner in which the veins ramify in the parenchyma; that one class of forms is produced when the veins pass straight from the top of the petiole to the margin; another class when they curve inwards, and grow to one another without touching the margin; a third, if they pass in parallel lines from the base to the apex of the leaf, and so on. And hence the arrangement of veins has been made the fundamental principle of a classification of their modifications. Although this may be carried too far, and is certainly not free from objections, it is, nevertheless, the most convenient mode which has yet been devised. Upon this principle the three following primary groups have been proposed; of each of which we shall give some examples.

1. *Forked-veined.*
2. *Parallel-veined;* of which *straight-veined* and *curve-veined* are forms.
3. *Reticulated;* to which are referred the *ribbed,* the *radiated,* and the *feather-veined* leaves.

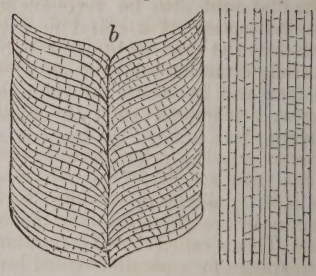
Forked-veined leaves are those in which the veins, whenever they divide, separate into a fork, the arms of which fork again, without forming a net-work by growing into some other veins. Instances of this are most usual in ferns (*fig.* 23), which are known by this among other characters.

Fig. 23.



Parallel-veined leaves have their veins proceeding from their origin to their termination without branching only connecting themselves by equally simple veinlets which pass off from them at right angles. Leaves of this sort are characteristic of endogens, in which they occur in two very distinct forms. The veins either pass straight from the lower to the upper end of the leaf running parallel with the mid-rib, as in grasses and lilies, whence they are called *straight-veined* (*fig.* 24, *a*), or they diverge from the mid-rib towards the margin, where they lose themselves and are called *curve-veined* (*fig.* 24, *b*), as in the Indian shot (Canna), the arrow-root plant (Maranta), and the plantain (Musa). The ragged appearance of a plantain tree, when exposed to wind, is owing to this cause: its leaves are long, heavy, and broad; and, consequently, offer much resistance to the wind; but they are also very thin, and easily torn; therefore, when this happens, the laceration will necessarily take place in the line of least resistance, which is from the edge to the mid-rib, parallel with the veins, and not across them. Palms, on the contrary, which are straight-veined plants, never exhibit the appearance of the plantain; but, if torn, rend from one end towards the other into long shreds.

Fig. 24.



Reticulated, or *netted,* leaves, are formed by the perpetual branching of veins, whose ramifications become gradually smaller and smaller; and growing to one another, divide the leaf into an infinite number of angular spaces, and form that beautiful net-work which is so much admired in the dissected leaves of the shops. In their most usual state the veins of these leaves proceed from the mid-rib at an angle more or less acute, towards the margin, sending off veinlets in their passage which meet and anastomoze

with the veinlets of other veins. The veins themselves curve inwards as they approach the margin, and finally grow to the back of the vein immediately before them, sending off throughout their whole length their delicate network of ramifications up to the very margin itself. The rose offers a familiar instance of this.

Fig. 25.

De Candolle has shown that the forms of leaves of this sort are very much dependent upon the relative proportions of the veins: thus, if all the lateral veins are short and of equal length, a leaf will be linear (*fig.* 25, *a*); if those of the middle are sensibly longer than the veins of the base and apex, the form will be elliptical (*b*), oblong, or even orbicular; but if the veins near the base are the longest and generally diminish towards the point, the leaf will be ovate (*c*); or if the longest veins are beyond the middle, obovate (*d*).

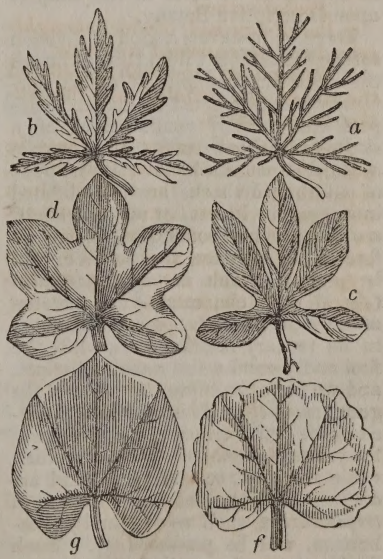
Sometimes the netted form is varied by the presence of several ribs which run side by side from the base to the apex, as in the melastoma and the dogwood; this is called *ribbed* (*e*), and may be mistaken for a parallel-veined leaf if attention be not paid to the netting of the veins between the ribs. In another state several ribs proceed like the rays of a circle from the point where the blade and the stalk of the leaf unite (*f*), as in the poplar, and form a radiated leaf. And, finally, in the oak and many other plants in which the veins proceed straight from the mid-rib to the margin, without bending inwards, the feather-veined form is produced (*g*).

It is not by the arrangement of their veins alone that the characters of leaves are affected; they are essentially determined by the manner in which the margin is directed: for this, although in some measure dependant upon the disposition of the veins, is itself, to a great extent, an independant phenomenon.

On this subject, as upon almost all others connected with the theory of vegetable structure, the older botanists held erroneous opinions. They considered a leaf to be a body originally undivided, which, owing to some unintelligible action, became cut into segments in different ways, so as to acquire eventually a lobed structure. There can, however, be no reasonable doubt that the explanation given of its nature by De Candolle is the true one. This distinguished botanist has entered much more at large upon this subject in his '*Organographie*' than is consistent with our plan; instead, therefore, of taking his words, we shall give an explanation of our own of the theory of the structure of leaves founded upon them.

We have already shewn that the stalk of a leaf is a bundle of vessels and fibre surrounded by cortical integument or parenchyma. At a certain distance from the stem the stalk begins to branch, and each branch carries with it

Fig. 26.



its own coating of parenchyma; every separate ramification, however minute, has also its parenchymatous envelope.

Suppose the ramifications to remain perpetually distinct, and merely to develope upon a plane without touching; and we have such a leaf as the capillary many-parted one of a water ranunculus, or of a hymenophyllum (*fig.* 26, *a*).

Let, however, the ramifications of such a leaf grow together at their edges in a slight degree, and a leaf like that of jatropha will be the result (*b*). Suppose the mutual adhesion of the contiguous edges take place still further, and the leaf of meadow geranium will be the result. If all the secondary ramifications of that leaf grow together, we shall have the digitate form of the common passion-flower (*c*). The principal divisions of this last united halfway up will produce a five-lobed leaf like that of sterculia platanifolia (*d*); still more consolidated, the crenelled leaf of dichondra will be the result (*f*). And, finally, if a coalition of all the exterior ramifications be completed, we shall have the entire orbicular leaf of the common asarabacca (Asarum) (*g*).

This explanation has thus been applied to a particular class of structure, —namely, the radiated; but it must be obvious that it is equally applicable to all other forms. For the terms that are employed to describe all these and other modifications we refer to the chapter upon Descriptive Botany.

There is, however, a kind of division somewhat different from this, although the same in principle, of which particular mention must be made. Suppose the primary ramifications of a skeleton feather-veined leaf to remain quite distinct, while the ramifications of all their divisions are consolidated into separate leaves, or rather leaflets, and a sort of compound leaf, such as we find in the liquorice, the pea, &c., will be produced; this is called *pinnated* (*fig.* 27, *a*). Now, imagine the skeleton of the same leaf to become consolidated in its tertiary ramifications, while the first and second veins remain distinct, and we have the bipinnated leaf of the gum acacia (*b*). It is possible to conceive the fourth order of ramifications of the venous system to be grown together, while the first, second, and third are distinct, and the unusual structure of *tripinnation*, such as is found in thalictrum, will be produced (*c*). Such divisions may be carried still farther, but the only name which is then applied is *supradecompound*.

Leaves thus deeply divided are commonly called *compound*, while leaves which are less than pinnated are said to be *simple;* but these terms are now

Fig. 27.

restricted otherwise. When a petiole is jointed with the blade, or with the leaflets, the leaf is considered compound, whether the blade be undivided or not; and, on the other hand, the most deeply or frequently divided leaves are considered simple, if no articulation exists between the blade and the petiole. Thus the leaf of an orange is compound, of a palm simple.

Chapter XI.

Of Leaves continued; their unusual modifications of Form.

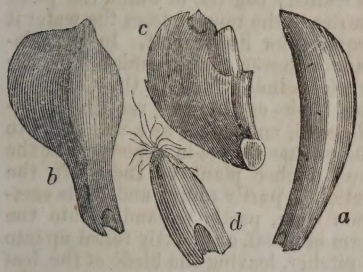
Besides the variations in the external structure of leaves treated of in the last chapter, there are others which, being exceptions to general rules, deserve to be noticed separately.

These exceptions are chiefly owing to five causes, or to a combination of more than one of them, namely, 1, a turgid state of all the parts, owing to the parenchyma being excessively succulent; 2, a general or partial diminution in size; 3, an excessive expansion of particular portions; 4, an unusual contraction and hardening of parts which are generally broad and leafy; and 5, the growing together of parts which are usually distinct.

It is to the extreme succulence and

consequent distention of the parenchyma in a particular direction that the singular leaves of the mesembryanthema are indebted for their curious forms. In one species they are *scimetar-shaped* (acinaciform) (*fig.* 28, *a*), because the parenchyma increases in thickness from the front to the back, while the width is not augmented in a corresponding degree; in others they are *axe-shaped* (dolabriform) (*b*), or deltoid (*c*), from the action of the same cause in a different direction; or they may be cylindrical conoids (*d*), as in mesembryanthemum barbatum, or the

Fig. 28



common onion, in which latter they are also hollow, because the circumference of such a leaf grows faster than the centre, which is in consequence torn and left without parenchyma to fill it up.

A general or partial diminution in the size of parts produces some great deviations from the usual structure. If all the parts are reduced to their smallest size, such leaves as those of the moss, which are mere minute and thin scales, or of lathræa and similar parasites, which are larger and more fleshy, but still mere scales, may be the result. But if the diminution in size take place only partially, it will simply be attended by a loss of symmetry, which will hence cause remarkable changes in appearance. In Begonia, for instance, one side of the leaf is considerably smaller than the other, and it becomes what botanists call *oblique*, or one-sided (*fig.* 29, *a*); in a pinnated leaf, the leaflets of one side may disappear, as in anthyllis and others (*b*). These circumstances are always caused, according to De Candolle, by the situation of such leaves upon the stem being more favourable to the development of one side than of the other; but this statement is scarcely borne out by facts, which seem rather to stand isolated and incapable of explanation from any secondary cause.

Fig. 29.

The excessive expansion of particular portions is much more frequently productive of singularity of form than any of the preceding. The expansion of the petiole in the orange (*fig.* 30, *a*), and the dionæa gives that part very much the appearance of a leaf; a similar structure in the compound leaf of a begonia from Madagascar, combined with the non-formation of leaflets, converts the petiole into what has been called a lomentaceous leaf (*b*); and a similar loss of leaflets connected with an excessive expansion of the petiole forms the *phyllodia* of the so-called leafless acacias of New Holland (*c*, *d*, *e*).

Fig. 30.

When certain parts of the leaf contract and harden, *spines* are formed, as in the edges of the common holly leaf, where the hardening is confined to the lobes; and in the berberry, which has the principal veins of its leaves separated and hardened (*fig.* 31, *a*, *b*). In a species of prosopis, the one half of the leaflets contracts into a spine, while the other half remains leafy. But the most singular instance of this kind of deviation from usual structure occurs in a palm called desmoncus (*c*), in

which the upper leaflets of its pinnated leaves contract and curve into scythe-shaped hooks by which the desmoncus climbs, while the lower leaflets retain the usual appearance of leaves.

Fig. 31.

But none of all these causes produces so strong an effect upon the general appearance of a leaf, or tends so much to render it unlike itself, as the adhesion of one part to another, especially if accompanied by some of the alterations already spoken of. Thus in the iris the leaves resemble the blade of a straight sword with one edge turned towards the sky, and the other towards the earth. This, which is called *equitant*, is caused by the leaves folding up, and their faces forming an adhesion with each other (*fig.* 32, *e*). In the nasturtium (*fig.* 32, *a*), the two

Fig. 32.

lobes of the base of the leaf grow together, so that the stalk looks as if it proceeded from the middle of the leaf, the latter becoming what is called *peltate*. In the honeysuckle the stem seems to grow through the leaves, in consequence of the base of two opposite leaves adhering; a similar appearance is produced in bupleurum, by the bases of each alternate leaf curving round the stem, and then growing together into a *perfoliate leaf* (*b*). But it is when a leaf, or some part of it curves inwards till the opposite margins touch, and then grow together, that the most singular appearances are produced. What are commonly called pitchers originate thus. In some species of dischidia the blade of the leaf acts thus, and at the same time becomes enlarged and succulent; the consequence is a sort of leathery bag (*c*), in which the plant carries to the tops of trees the water it requires for its support. In the side-saddle flower (Sarracennia) it is the whole petiole which is thus affected, the blade of the leaf remaining unchanged, and acting as a sort of lid to the pitcher; while in nepenthes, or the true pitcher plant of India (*d*), the petiole is partly round, and, in its common state, partly expanded into the form of a leaf, and partly rolled up into a pitcher, leaving the blade of the leaf at its extremity as a cover to the pitcher.

Thus it appears that all the varied forms of leaves are to be reduced to one primitive type, from which they are deviations, and which are to be explained upon perfectly simple and intelligible principles. It will hereafter be seen that the leaf is the type of forms still more remarkable than any now mentioned, and having a totally different class of functions to perform.

Chapter XII.

Of Leaves continued; their internal Structur

The universal presence of leaves upon all plants, their highly complicated structure, the intimate connexion which it has been shown that they maintain between the systems of the wood and bark, their extremely high development in many cases, and their multiplied variety of form, all lead to the opinion that they are organs of the most essential importance. This is confirmed by their internal structure, independently of experiment.

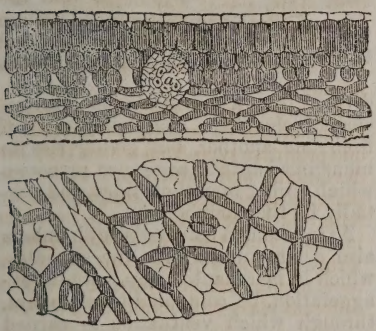
Most leaves are no thicker than a piece of paper or parchment, and appear to the naked eye as nothing more than a thin green plate, so that an

ordinary observer would never suspect that their internal structure, which no eye, unassisted by glasses, can investigate, was one of the most complicated and highly-organized character; and yet there is no part among those with which plants are furnished which is more complex. It is necessary, indeed, that it should be so, in order to be enabled to perform the important functions of digestion, respiration, and perspiration, for which it is destined.

This subject has been very carefully investigated by Messrs. Mohl, Adolphe Brongniart, Meyen, and Mirbel, to whom we are chiefly indebted for our knowledge concerning it. Perhaps the most simple mode of explaining the result of their observations will be to take some common kind of leaf as a type, of which all others may be considered modifications. For this purpose we will select the apple.

The leaf of an apple-tree (*fig.* 33)

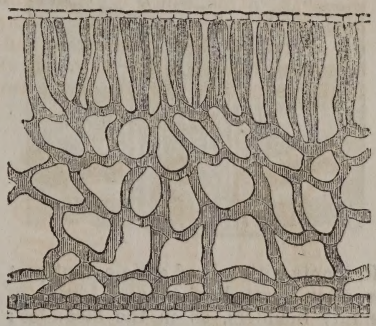
Fig. 33.



consists of a mass of parenchyma, through which pass bundles of vessels and wood tubes in the form of veins; the whole of which is enclosed between two extremely thin plates of cuticle which are united at the edge of the leaf. This cuticle consists of a single layer of minute bladders containing air, and pierced with stomates which are generally much more numerous on the under than on the upper side. Beneath the skin of the upper side are about three layers of cylindrical bladders filled with green pulp, which are packed closely together *perpendicular* to the skin, but with minute cavities between the bladders, and more open spaces caused by the total separation of the bladders beneath each breathing pore. Beneath the skin of the under side are four or five layers of similar cylindrical bladders lying *parallel* with it, touching each other only at their ends, and forming the sides of a number of chambers which communicate freely with each other. This lower layer joins the upper layer, thus dividing the whole of the inside of the leaf into two portions, the constituent parts of which are perpendicular to the upper surface and parallel with the lower; the upper, where the skin has comparatively few stomates, being very compact, the lower, where the stomates are numerous, being very lax and cavernous; a beautiful adjustment of parts most admirably adapted to the functions of the leaf, as will be hereafter shown.

This is the common structure; that side of the leaf being the most cavernous where there is the greatest number of stomates, and the reverse. Thus, in the water lily (Nuphar) (*fig.* 34), in which the lower side of the leaf has no stomata, the compact structure of bladders is on that side, and the cavernous parenchyma is on the upper, where the stomata are extremely numerous.

Fig. 34.



In succulent plants, whose leaves have neither upper nor under surface, the parenchyma is of equal density throughout; in leaves which are constantly under water, as in many floating plants, the skin is entirely absent, and the cavities of air are distributed equally through the whole mass of the parenchyma (*fig.* 35); and in thin leaves, such as the Iris, the two sides of which are exposed alike to the action of light, in consequence of their edges being vertical instead of horizontal; the parenchyma next the skin is cavernous on both sides with perpendicular bladders,

while the centre is often filled with compact parallel bladders. The following section of the leaf of a pine-tree (*fig.* 36), copied from Adolphe Brongniart, in which *a* is a bundle of vessels; *b b*, parallel compact bladders of the centre; *c c*, the perpendicular bladders of parenchyma filled with air cavities; and *d d*, the skin of the two surfaces, illustrates this.

Fig. 35.

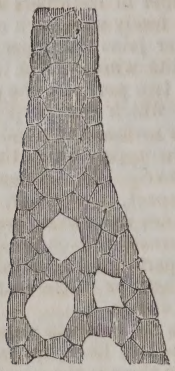
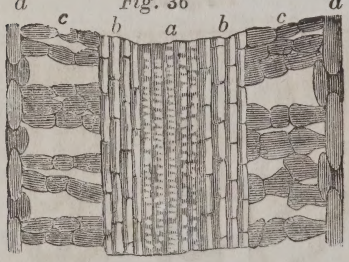


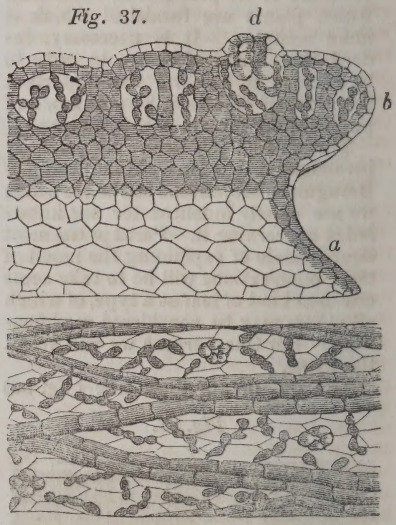
Fig. 36



In plants with a hard cuticle, that part is often formed of several layers of empty bladders, as in the oleander; and in mosses, and plants which have very imperfect leaves, two or three layers of thin-sided bladders often constitute the whole mass, without distinction of skin from parenchyma.

In marchantia, the structure is, if possible, still more remarkable than in the instances already cited. This plant, which, in the hands of Mirbel, has been the subject of the most profound and complete examination that has yet been instituted in vegetable physiology, has been found by that skilful observer to consist, on its under side (*fig.* 37, *a*), of a thick layer of nearly empty bladders, firmly arranged without air cavities, and not covered by skin; but on its upper surface (*b*), where alone stomates occur, it is covered by a skin, beneath which the parenchyma is filled with green pulp, and

Fig. 37.



divided into a multitude of lozenge-shaped chambers completely cut off from one another, but giving rise to numerous jointed deep green processes which spring from their sides, and partially fill the chambers (*c*).

As in common leaves, these chambers also communicate with the stomates, which in marchantia may, without exaggeration, be compared to chimneys, through which ventilation is carried on (*d*).

What has hitherto been stated refers only to the parenchymatous structure of leaves. The venous system which pierces them in every direction consists of vessels surrounded by woody tubes, which stiffen and protect the former (*fig.* 33 and 36, *a*): these are largest near the base of the leaf, and gradually diminish in thickness towards the extremity of their ramifications, till they altogether lose themselves in the parenchyma. To the eye, aided by the most powerful microscopes, the veins seem to be altogether single; but it is well known that when a leaf has been macerated till the parenchyma is quite decayed, the veins will separate into an upper and a lower stratum, so neatly and regularly, that it is impossible to doubt their having

originally consisted of two distinct systems, the one placed above the other. As the sap is propelled from the wood into the leaf in a crude state, and returned into the bark in an elaborated state, and as the veins of leaves are evidently connected with both the wood and the bark, it is supposed that the upper of the two layers is for the onward flow of the crude sap, and the lower layer for the backward flow of the elaborated sap; but there is no distinct evidence of this opinion being well founded.

The anatomical structure of the leaf appears distinctly connected with its functions of respiration and evaporation. That side of the leaf which is next the sun being most exposed to heat, the cylindrical bladders that form it are placed with their narrow ends next the cuticle, by which means they not only each present the smallest evaporating surface, but are so circumstanced with respect to each other, as to be able, with the least difficulty, to absorb fluid from each other as they empty. The bladders next the lower surface not being exposed to the same kind of external influence, do not require the same kind of internal adjustment of their parts, but are arranged with wide intervals between them, which communicate with the chambers below the numerous breathing pores of the lower surface. Here, then, the functions of respiration are best performed, each bladder, on the one hand, exposes the greatest possible extent of surface to the action of the oxygen or carbonic acid that may be received by the breathing pores, and has, on the other, the greatest possible power of parting, firstly, with the oxygen, which results from the decomposition of the carbonic acid in these vegetable stomachs, and secondly, with the superfluous water, which is not evaporated by the upper surface through the cuticle. It will be observed, that in the water-lily (*fig.* 34), in which the most cavernous part of the parenchyma is next the upper surface, the leaf floats with its lower face upon the water, respiration consequently cannot take place at the under surface, and the function is of necessity transferred to the upper, where the stomata all are.

From these statements it is to be inferred that leaves are a sort of pneumatic apparatus, of a highly-curious and elaborate structure; and that the variations which occur in their internal organization are beautiful adaptations of the parenchyma to the particular circumstances under which the leaves themselves are placed.

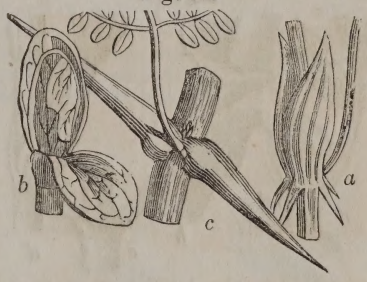
Chapter XIII.

Of Stipules, Tendrils, and Hooks.

The *stipules* are, in many respects, analogous to leaves; like those organs they are often green, lobed, or otherwise characterized; they frequently have buds in their axils, as in the peach and the willow; and they sometimes are not distinguishable from leaves by anything in their form, colour, or consistence. Nevertheless they are, in most cases, sufficiently different from leaves, and are always to be recognised by their position at the base of a leaf, one on each side.

In their most complete state they are little leafy bodies, as in the vetch (*fig.* 38, *a*) and the pea; they are large, lobed, green organs in the heart's-ease (*fig.* 1, *d*); in the tulip tree they are flat, oblong, undivided membranes (*fig.* 38, *b*); in the bird cherry they are

Fig. 38.



nothing more than fine green bristles; and in other plants, as buckthorn for instance, they are frequently reduced to the state of a minute withered scale. By hardening and becoming conical, they resemble spines in some mimosas (*c*); and by losing their parenchyma, and lengthening their mid-rib, they are transformed into long, soft, thread-like processes, which will twine round neighbouring bodies, and thus support the weak and slender stem in the air, as in gourd-like plants. They are then real tendrils.

By adhesions either with each other, or with the leaf, they sometimes alter their appearance in a remarkable de-

gree. In magnolia, they grow together by their upper end, and rolling round the young buds, form a long horn-like sheath, which effectually protects them till they are ready to unfold. The pondweed (potamogeton) has a structure analogous to the last (*fig.* 39, *d*). In cinchonaceous plants they adhere sometimes by one edge, sometimes by another; but most commonly the two contiguous stipules of a pair of opposite leaves unite by their edges, and grow into a scale placed between their two footstalks, which is called an interpetiolar stipule (*fig.* 39, *c*). In polygonum they are thin, rolled round the stem, and united to each other by both edges, so as to form the sheath to which the name of *ochrea* is technically given (*b*). In the rose they grow to the edge of the footstalk, of which they become a thin, leafy margin. And finally, in alternate-leaved plants they are sometimes large enough to surround the stem and unite where they meet on the side opposite to the leaf, which is then called *synochreate* or *hypoglottideous*, as in many species of astragalus (*a*).

Fig. 39.

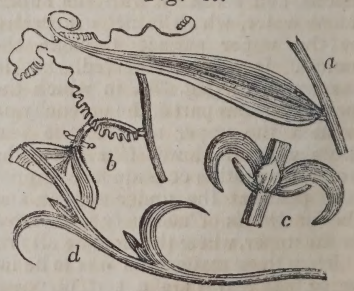
Many other modifications might be pointed out; those now explained will serve to show that the stipules are such variable organs, that neither form, texture, size, nor colour will define them; but that they are simply characterized by being placed *at the base of the leafstalk*.

The use of stipules in their most complete state is supposed to be to protect the young leaves; such at least seems to be the case in species whose stipules are very highly developed: in the fig and magnolia, for example, they roll round the leaves till the latter are large enough to burst through them, and are able to bear exposure to the air without injury and in the tulip-tree (Liriodendron tulipifera) they act like two dishes which fit together by their edges, and enclose the young leaves in their concavity (*fig.* 38, *b*). But it is difficult to believe that protection is the only office these organs have to exercise, for in by far the greater number of cases they are so small as to be unable to perform any such purpose. If instances of their being rudimentary bodies were rare, instead of so very common, it would be easier to believe that the business of stipules is really that which is assigned to them.

Tendril is a name given to any part of a plant which is thread-like and capable of twisting round neighbouring plants; it cannot, therefore, be referred to any particular class of organs. In the vine it is a transformation of flowering branches; in the gourd it is an altered stipule; in the pea it is the extremity of the petiole; in gloriosa it is the point of the leaf (*fig.* 40, *a*), which is nearly the same thing; in nepenthes it is the cylindrical part of the petiole; and in the singular genus strophanthus it is actually the points of the petals which have become tendrils, and twine round other plants.

Hooks, which, like tendrils, are contrivances by which weak plants cling to those that are stronger, are also mere adaptations of other organs to that purpose. The hooks of uncaria (*fig.* 40, *c*) are abortive branches, leafless, spiny, and very much curved; those of combretaceæ are produced by the hardening of the petiole after the leaf has withered; and in the singular genus ancistrocladus they appear to be also petioles, but of leaves which never develope in any other form (*d*).

Fig. 40.



Chapter XIV.

Of Bracts.

All the parts hitherto treated of belong to what are called *the organs of nutrition or of vegetation.* Their office is so strictly conservative, that nothing has been assigned to them beyond the power of absorbing crude food from the earth by the roots, altering it a little in the stem, digesting and separating it in the leaves, and storing up in the bark and wood the matter thus altered and inspissated. Every thing which is developed subsequently to the leaves belongs to the *organs of reproduction* or *of fructification;* the sole office of which is to secure the perpetuation of species by seed,—an action they are enabled to perform by the nutrient properties of the stem and leaves.

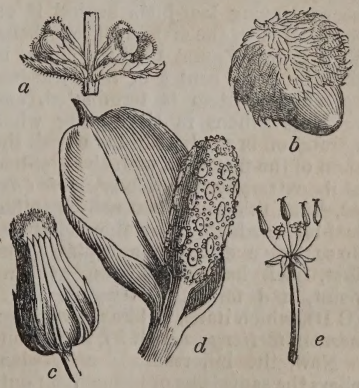
A little below the flower, interposed between it and the leaf, from the axil of which it arises, are, in the Heart's-ease, one or two little scales, which are evidently organs in an exceedingly rudimentary state. Botanists call them *bracts* (*fig.* 41, *a*), and suppose them, when sufficiently large, to be destined for the protection of flowers before they unfold; but they are frequently in an extremely imperfect state, and quite unfitted for such a purpose.

Although bracts are so exceedingly minute in the Heart's-ease, and, in such plants as we are most in the habit of examining, are seldom so large as ordinary sized leaves, or of any other colour than green, yet they are sometimes of remarkable dimensions, and coloured white, or purple, or crimson, or some other gay tint, and then receive the especial name of *spathe* (*fig.* 41, *d*). An instance of this we find in the Cuckoo-flower of our own hedges (Arum maculatum); in some foreign Arums the spathe is very much larger than in our indigenous species; but it is in Palms that this part acquires its most extraordinary dimensions. The spathe of Alfonsia amygdalina, a South American species, is computed to contain upwards of 200,000 flowers; and that of Corypha Taliera, an East Indian palm, is often as much as twenty feet long.

When bracts are collected into a whorl, as in umbelliferous plants, they are said to form an *involucre* (*fig.* 41, *e*), which, if very small, receives the diminutive name of *involucel.* This kind of organ is very remarkable in compound-flowered plants, appearing as if it constituted a calyx common to many flowers (*fig.* 41, *c*); and hence it used to be called a common calyx. It however does not differ from the involucre in any thing more than its bracts being more numerous, more closely packed, and parallel with each other, instead of diverging. *Periphoranthium* and *periclinium* are names given by foreign botanists to this kind of involucre.

Sometimes bracts not only collect in a whorl, and grow parallel with each other, as in the true involucre, but they actually grow together into a solid cup-shaped body, their points only remaining distinct: such is the cup, or *cupule,* of the acorn (*fig.* 41, *b*). The real nature of this part is not very obvious in our wild oaks, but it may be distinctly observed in the cupules of the mossy-cupped, or Turkey oak (Quercus cerris), which is common in plantations. If the young acorns of that species are examined, the cup will be found to consist of numerous whorls of bracts loosely cohering, and evidently not distinguishable from common bracts; as it gets older they grow together by their lower ends, till at last the acorn cup is fully formed. In Grasses and Sedges the flowers seem to be composed of nothing but bracts, in different states, packed closely one over the other; in these instances we must suppose they perform the office of calyx, whatever that office may be.

Fig. 41.



Bracts being thus variable in their appearance, their limitation becomes proportionably difficult. The best perhaps is that which defines them to be all leafy bodies which intervene be-

tween the calyx and the leaves. To this, however, the impossibility of determining, in some cases, where the calyx begins, is an objection. (See Chap. XVI.) Difficulties of this kind arise, out of the very nature of things, and are consequently not to be overcome, as will be hereafter explained. (See Chap. XXV.)

As all leaves have the power of forming leaf-buds in their axils, so have all bracts the power of forming flower-buds in their axils; and it rarely happens that flowers occur which do not thus originate. Hence it is a general rule, that where bracts are found, flowers may also be expected.

Chapter XV.

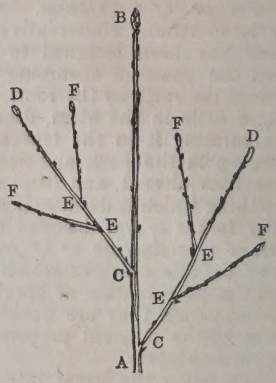
Of the Inflorescence.

The manner in which flowers are arranged upon a stem, or, more correctly, upon that part which bears the flowers without lengthening into a leaf-bearing branch, is called the Inflorescence. A variety of different forms is mentioned by botanists, and it is found necessary to distinguish them with care for systematic purposes; but they are, in reality, all modifications of two primitive types, which, if well understood, will readily explain the origin of the others.

In order to make this intelligible, we must consider upon what principle branches ramify. When an embryo plant shoots up its first stem, it is terminated by a growing point, which keeps leaving leaf-buds behind it on the surface of the stem as it lengthens. This growing point finally occupies in the winter the centre of that leaf-bud by which a stem is terminated, and again lengthens in the spring when vegetation is renewed. Let us call the stem of the first year, with the leaf-bud at its extremity, the *primary axis* (*fig.* 42, A B); this part is covered with other leaf-buds, which, when they lengthen, do so upon exactly the same plan as the first, each having its own growing point, and forming a *secondary axis* (C D), which itself, in like manner, generates *tertiary axes* (E F), and so on.

Now, the inflorescence of a plant obeys the same laws of branching; only for leaf-buds we have flowers. And the two primitive types to which all modifications of inflorescence are reducible, depend upon whether the growing point of the primary axis has the power of lengthening indefinitely or not. If it have the power of growing indefinitely, inflorescence is said to

Fig. 42.



be *indeterminate;* if its powers of lengthening are uniformly arrested at an early period, inflorescence becomes *determinate;* these being the original causes of the various forms of branching we meet with among flowers.

§ 1.—*Indeterminate Inflorescence.*

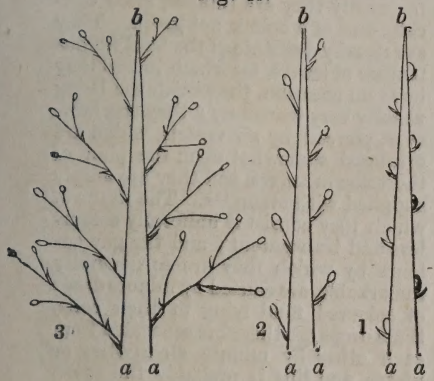
The characteristic of this is, that the primary axis is not arrested in its growth at a very early age, but its secondary, tertiary, or other axes are; and it comprehends some of the most common modifications. Let the lines *a a*, *b* (*fig.* 43), represent such an axis, the lateral buds or secondary axes of which are flowers. As those buds which are nearest *a a* were the first formed, they must of course be the oldest; they will therefore be the first to open; and consequently the flowers, when they expand, will do so first at *a a*, and last at *b*, or in an ascending order. This order of flowering is called *centripetal*, because *a a* is considered to represent the circumference of a cone of which *b* is the apex or centre. Now, suppose that while the primary axis *a a*, *b*, is indeterminate, all the secondary ones *o*, *o*, *o*, are determinate, and have no power whatever of lengthening (*fig.* 43, 1), an inflorescence will be produced analogous to that of the Rib-grass (Plantago): this is called a *spike;* or if it only bears barren flowers, and drops off after shedding the pollen, as in the Hazel, an *amentum* or catkin; or if it is covered very densely by flowers, and is enclosed within a spathe,

as in Arum, it receives the name of *spadix*.

But if the secondary axes *o*, *o*, *o*, have the power of lengthening equally, without however producing tertiary axes, a *raceme* (*fig.* 43, 2) is the result, as in the Currant.

And if the secondary axes develop tertiary axes (*fig.* 43, 3), a *panicle* will be formed, as in Poa annua, which will be more or less compound according to the number of degrees of its ramification. When the upper and lower branches are shorter than those in the middle of a panicle, as in the Lilac, we have a *thyrse*.

Fig. 43.



§ 2.—*Determinate Inflorescence.*

Forms referable to this type are distinguished by the primary axis being arrested in its growth, before the purposes of flowering are at an end; the consequence of which is, that determinate inflorescences, if consisting of more than one flower, are broad instead of being long. A solitary flower, such as that of the stemless Gentian, is taken as a type of this. It consists of a primary axis terminating in a single flower. An idea of it may be obtained from *fig.* 44, 1, in which the lines *a a b* represent the primary axis, bearing bracts from which secondary axes do not arise.

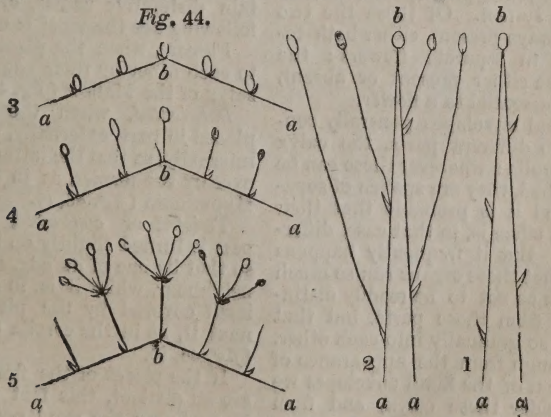
Now, let secondary axes arise from this, of which the lowest are longer than the uppermost, and each long enough to be elevated as high as the central flower, and we have a *corymb* (*fig.* 44, 2).

Suppose the primary axis to be exceedingly short, and the buds of secondary axes to be closely crowded upon it; if, in such a case, the secondary axes do not lengthen, but merely unfold their flower, as in *fig.* 44, 3, a head or capitulum, like that of the Dandelion, is the consequence, in which the axis is distended laterally, in order to make room for the flowers.

But if, while the primary axis is very short, the secondary axes lengthen partially so as to form stalks to the flowers, as at *fig.* 44, 4, an *umbel* will be formed, which umbel will become *compound*, if the secondary axes develop upon the same plan as the primary (*fig.* 44, 5).

Hence it is evident that the head is a spike with a short primary axis, the umbel a raceme, and a compound umbel a panicle in the same condition. All these forms follow the centripetal order of flowering.

Fig. 44.



But there are other determinate forms of inflorescence in which a *centrifugal* order takes place; that is to say, in which the uppermost, or most

central, flower opens first, and the lowermost, or most external, last. In these cases the theory is, that it is not till after the central flower is formed that the lateral ones begin to develop, and that consequently the central flower, in such instances, is really the oldest. A bit of the Laurustinus (Viburnum tinus, *fig.* 45) shows this very well.

Fig. 45.

If this sort of centrifugal development resembles a panicle, or rather an irregular umbel, as in the Laurustinus, it is called a *cyme.*

When what would otherwise be a capitulum expands its flowers centrifugally, it is called a *glomerule.*

And if a cymose arrangement of the parts is much contracted and but little branched, as in a Sweetwilliam, we have the *fascicle.*

Chapter XVI.

Of the Floral Envelopes.

A PERFECT flower consists of three principal parts; namely, the *floral envelopes*, the *fructifying system*, and the *fertilizing system.* Of these the two last are always present, either both together or in separate flowers; the first may be either present or absent, not being essential to a flower.

The floral envelopes generally consist of two different parts, the calyx and the corolla: wherever these can be distinguished, they are spoken of separately; and it is probable that their respective office is, in that case, different also. But it frequently happens not only that these organs run so much into bracts as not to be readily distinguishable from those parts, but that they pass so gradually into each other, that although from the appearance of the external of the floral envelopes we may consider these calyx, and from that of the internal ones we can suppose those to be corolla, yet we are quite at a loss to know where the outer ends, and the inner begins. This happens in the Carolina allspice (Calycanthus), the white Water-lily (Nymphæa), and various other plants. To designate such cases, the word *perianth*, or *perigone*, has been contrived; and in descriptive botany is employed to express floral envelopes consisting of several whorls of parts passing gradually into each other. This seems to show that whatever the calyx and corolla may be, they are extremely similar, or, indeed, identical in nature.

In some cases the parts of which they are composed are green like leaves, particularly in the calyx; but most frequently they are thinner, more delicate, and of a colour not green. They are usually destitute of the hard fibrous texture of leaves, for which indeed they have no occasion, their existence being usually very transitory; they are, however, pierced by air-vessels, which are arranged somewhat upon the plan of the veins in leaves, and they are amply supplied with stomates. The tissue of which they consist is uniformly colourless and transparent; and the gay colours by which they are so generally remarkable, are caused by minute drops of coloured fluid lying in their cells. Such drops are therefore separated from each other by minute air-cavities or plates, and this is probably the cause of the beautiful satiny lustre we find upon almost all petals.

The manner in which the pieces of the floral envelopes are respectively arranged in the flower-buds is called their *æstivation*, and has received certain distinctive names, of which the following are the most remarkable.

Valvate, when the pieces fit exactly to each other by their edges, as in the calyx of the Mallow (*fig.* 46, *a*).

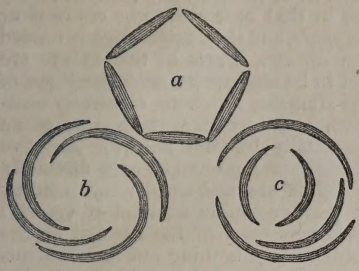
Imbricated, when the pieces are placed in part externally, and in part internally, so that the latter are covered over by the former, as in the calyx of Hypericum (*fig.* 46, *c*).

Twisted or *contorted*, when each part is turned slightly on its own axis, so that by one of its edges it covers its neighbour, while it is, in like manner, itself covered by the piece which is next it, as in the corolla of a Mallow (*fig.* 46, *b*).

If the pieces of the floral envelopes are all distinct, this fact is expressed by prefixing the word *poly* (many) to the part which is spoken of, as *poly-*

sepalous, if the calyx consists of several pieces or *sepals*; and *polypetalous*, if the corolla consists of several *petals*.

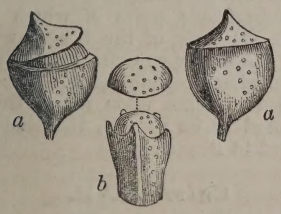
Fig. 46.



But if the pieces grow together by their edges and form a tube or cup, we then say *monosepalous* or *monopetalous*, that is, *one-sepaled* or *one-petaled*; by which is to be understood that they are all grown into one, and not that such a tube or cup is only one piece notched at its edge. The Greek privative *a* is also employed to designate their absence, as *asepalous*, or *apetalous*.

Sometimes the upper part of the floral envelopes grows into a solid lid, and separates from the lower, falling off like a cap; this happens to the calyx of Eucalyptus (*fig.* 47, *a*), and to the corolla of Eudesmia (*fig.* 47, *b*).

Fig. 47.

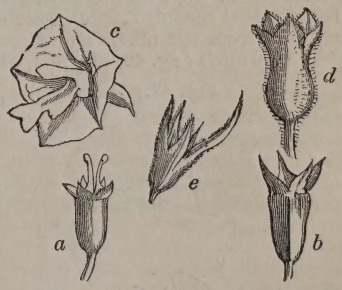


Calyx.—When the calyx is distinguishable from the corolla, it is commonly known by being smaller, greener, and more leaf-like, or more permanent. But such characters will not always indicate it, for we find it more richly coloured and larger than the corolla in the Fuchsia, and more deciduous in the Poppy. In fact, there seem no means of defining the calyx better, than as the most exterior whorl of the floral envelopes; and consequently the name is so applied, whatever the colour, size, or other characters of the exterior whorl may be; and hence if there is only one whorl, that one is calyx. Care, however, must be taken, when the sepals and petals grow together into a tube, that such a circumstance does not prevent our perceiving the presence of two whorls, as in the Crocus, in which a careful examination will show that there are really two whorls, each consisting of three pieces, one on the outside of the other, and consequently that both calyx and corolla are present.

The calyx frequently drops off when the flowering is over, but sometimes it continues to grow for a long time afterwards. Thus in the Gaultheria and the Strawberry-blite, it becomes red and succulent; in Christ's thorn (Paliurus australis), it expands into a broad thin woody rim; and in the black varnish tree of Burma (Melanorhæa usitatissima), it grows from little green scales into as many large, leafy, veiny, red parts, looking like a corolla surrounding the fruit.

Not only do the sepals grow together and form a tube or cup, but they sometimes grow to the outside of the ovary, so as to become quite incorporated with it, as in the Apple. When this happens, the calyx is called *superior* (*fig.* 48, *a b*), for it looks as if it actually grew upon the ovary; while, on the other hand, it is called *inferior* (*fig.* 48, *c d e*) in its ordinary position, as in the Cherry. The French, with more reason, say it is *free* in the latter case, and *adherent* in the former; but the first-mentioned terms, although not to be defended, are in most common use.

Fig. 48.



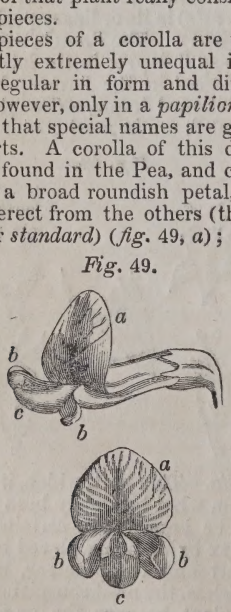
Corolla.—This part, which, it will be seen from what has lately been said, is only to be known with certainty from the calyx by its being placed between that part and the stamens, is often, nevertheless, the most conspicuous part of the plant, because the gay colours and the fragrant odours of flowers are generally resident in it.

The pieces, or *petals*, of which the

corolla consists, are sometimes so much narrowed towards the base as to be separable into two parts, just as a leaf may be separated into stalk and blade; in that case the stalk part of the petal is called the *unguis* or *claw*, and the blade has the name of *limb*. It is probably by petals of this sort that monopetalous corollas with long tubes are formed, the border consisting of the limbs, the petals and the tube of their claws in a state of adhesion. The orifice of such a tube is called the *throat* or *faux*. The petals alternate regularly with the sepals, and are usually either equal to them in number, or twice as numerous; but in consequence of the irregular way in which the petals and sepals respectively cohere, this cannot always be very well made out. For instance, in the garden Sage, the calyx has apparently two lips or parts, while the corolla has four; but if the former be attentively examined, its upper lip will be found to consist of three, and its lower of two sepals; while in the corolla the upper lip consists of two petals, and the lower of three, adhering unequally and irregularly. Hence the calyx and the corolla of that plant really consist each of five pieces.

The pieces of a corolla are not unfrequently extremely unequal in size, and irregular in form and direction. It is, however, only in a *papilionaceous* corolla that special names are given to the parts. A corolla of this description is found in the Pea, and consists of, 1st, a broad roundish petal, which stands erect from the others (the *vexillum* or *standard*) (*fig.* 49, *a*); 2nd, of

Fig. 49.



two oblong, parallel, slightly convex petals (the *alæ* or *wings*) (*b*), which conceal, 3rd, the *keel* or *carina* (*c*), which consists of two petals sticking together by their front edges.

Sometimes petals have membranous scales growing from their upper surface, as in the Catchfly (Silene); they are in that case said to be *crowned* or *coronate*, and their appendage is named the *corona*. Parts of this nature are not to be confounded with abortions of the stamens, which are extremely common, and very like them, but of an essentially different nature. Abortive stamens are processes of a distinctly fleshy nature, and usually traversed by at least one minute parcel of vessels; mere processes of the corolla, on the contrary, are nothing but membranous expansions of cuticle, without any distinct trace of vessels.

The office of the floral envelopes is in part to act as a protection to the fertilizing and fructifying organs when they are young, and to guard them from sudden variations in temperature, by the thin layers of air which they cause to be interposed between those parts and the atmosphere; but it is also probable, that when green, they act like leaves as elaborators of food upon which the organs of reproduction may be nourished, and that when coloured the corresponding change in their chemical operation still further contributes in a special manner to the same end by the conversion of crude fæcula secreted at their bases into sugar, the superfluous parts of which flow off in the form of the honey, which many flowers are so well known to yield in considerable abundance. For the detailed evidence upon which this is supposed to be proved, the reader is referred to Physiology.

Chapter XVII.

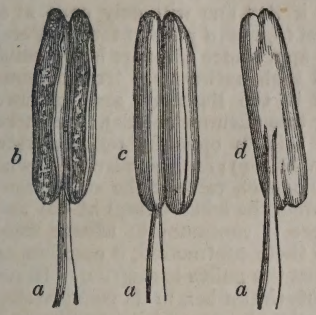
Of the Stamens, or Fertilizing System.

The fertilizing system, called by many modern writers the *andræceum*, consists of the organs which are arranged between the floral envelopes and the pistil, or fructifying system. Such organs are technically named *stamens*, and usually consist of two parts, viz., a slender white stalk or *filament*, and a yellow or brown head or *anther*. Of these the essential part is the anther, the filament being of no more importance to the latter than the foot-stalk to the leaf.

An accurate idea of the normal state

of the filament and anther may be taken from the Lily. In that plant the filament is a long, fleshy, awl-shaped, greenish-white body (*fig.* 50, *a*), the

Fig. 50.



surface of which is furnished with stomates, and the centre with a bundle of vessels. On its point is placed the anther (*b c d*), which is a narrow, reddish-brown body, having a deep furrow passing down its longer diameter, and being thus separated into two parallel lobes. The part that unites the lobes is a continuation of the filament, and is called the *connective*. Each lobe, before it opens, is marked in front by a shallow furrow which passes from end to end of the lobe, dividing it into two somewhat equal parts (*c*). In course of time the sides of the lobe contract and separate at the last-mentioned furrow, which consequently opens (*b*), and allows a brownish-orange powder, named *pollen*, to fall out; the two sides of the lobe when they thus separate are called *valves*, and the furrow itself the *suture* or *line of dehiscence*. The anther of a Lily, therefore, consists of two parallel lobes, united by a connective, each formed of two valves opening by a longitudinal suture and discharging pollen. This may be considered typical of all filaments and of all anthers. Both these parts are, however, subject to numerous important modifications.

The filament owes the chief differences in its appearance to *flattening*, *distension*, or *contraction*. When exceedingly flattened it becomes so like a petal that it can only be distinguished from that part by its bearing an anther (*fig.* 51, *a c h*); this happens in the Indian shot (Canna), and in a less degree in the white Water-lily (Nymphæa). Distension acts in the most remarkable manner at the base, where it causes the filament to assume the appearance of a fleshy scale (*b*), as in Zygophyllum and Campanula. In a state of contraction it becomes a mere thread, as in Grasses; and even disappears altogether as in a great variety of plants. It is generally smooth, but in the common Spiderwort (Tradescantia) it is covered all over in the middle with long, necklace-shaped hairs, arranged in a dense tuft; in this state it is called *stupose* (*fig.* 51, *d e*).

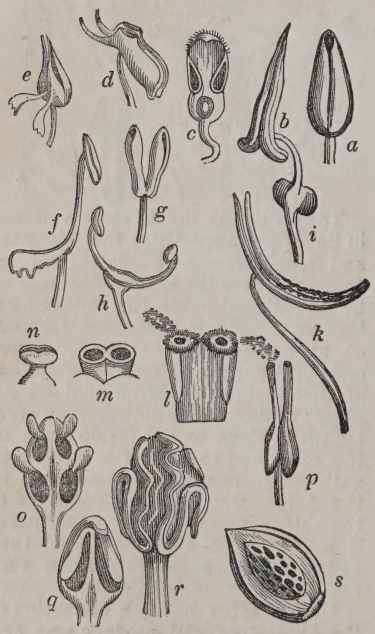
Fig. 51.

The anther is much more variable in its appearance than the filament, and from causes of a different nature. In cases where the lobes unite so as to be undistinguishable, the anther may become absolutely one-celled (*fig.* 52, *a*), as in Epacris, or it may be two-celled, without any external indication of that fact, as in Arum and all its allies; or finally, the sutures may grow by their edges to the inside back of the cells, and so convert a two-celled anther into one with four cells, as in the Ash. But if one of the lobes of the anther is undeveloped, or abortive, it may become one-celled from that cause alone, as in the Indian shot (*fig.* 51, *a*).

On the other hand, a distension of the connective will produce very singular anomalies. Suppose that part to spread right and left without lengthening, as in the Monarda, the lobes will be at right angles with each other, instead of being parallel; and if they should grow together at their points (*fig.* 52, *n*), the anther itself will become one-celled from this cause, in addition to those before mentioned, as actually happens in the Mallow. Let

the connective grow much beyond the lobes without widening, and the horns of the anther of some Orchideous plants, the membranous crest of the Violet, or the fleshy crest of the Ginger tribe (*fig.* 51, *h*) (Scitamineæ), will be the result. A third modification of the appearance of this organ may arise from the connective growing much more on one side than the other, having no anther on the side of excessive growth, and also taking on that side a direction different from what is habitual to it in other plants. This is particularly remarkable in the Sage genus, the anthers of which are one-celled, and look as if they rode upon a two-legged body (the connective), which is itself astride of a slender fleshy process (the filament). See *fig.* 52, *f*.

Fig. 52.



Occasionally the lobes of the anther, instead of being parallel with one another, and at the same time straight, retain their parallelism, but fold and double up upon themselves; and this produces the sinuous appearance in the anthers of a Gourd (*fig.* 52, *r*). Or, finally, they may give birth to processes of different shapes, which give them a horned or spurred, or crested appearance, as in many plants of the Heath tribe (*e d*).

The manner in which the anther bursts, so as to allow the pollen to escape, is usually by an opening all along each suture, or line of dehiscence; but if that line will only open at one point (*fig.* 52, *d p m l*), as in the Potato, the appearance of a pore is the result; and such anthers are termed porous. But in the Barberry, and the Sweet bay tree (Laurus nobilis), the anthers are said to open by reflexed valves (*fig.* 52, *o q*); in those plants the whole face of each valve of the anther comes off from the lobes except at the apex, where it continues to adhere firmly, and there contracting, it curls up, and allows the pollen to drop out. In such plants the anther, in its young state, is exactly like one which finally opens longitudinally; but it would seem that eventually it is unable to expel the pollen by the usual suture, which will not give way to the force exerted by the pollen grains from within. It is, however, indispensable that something should give way, and, consequently, the face of the anther separates all round, and having separated, curls up in consequence of the contraction of all its parts.

In Mistletoe, the mode in which the anther opens is altogether anomalous: bursting when ripe by a number of holes which are scattered over its whole surface (*fig.* 52, *s*).

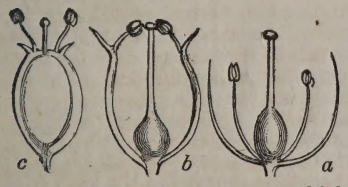
In their number the stamens follow no constant rule; for although it is certain, as will be hereafter proved, that their most normal number is, in all cases, the same as that of the segments of the calyx or of the corolla, yet, what with multiplication, abortion, and transformation, they are very often extremely different from the quantity of the floral envelopes. The only rule that can be said to be fixed concerning them is, that if they are fewer than the segments of the calyx or corolla taken separately, the difference is owing to a part of them being abortive or transformed; and if there is more than the segments, they are always in that case some multiple of the number of the latter, unless in consequence again of transformation or multiplication. For illustration of this position the reader is referred to Chapter XXV.

The stamens sometimes grow to one another, or to neighbouring parts, by both which circumstances their true

character is more or less masked. In the Mallow, the filaments of a great many stamens grow together into a tube, and are called *monadelphous;* in the Pea, they grow into two unequal parcels, and are *diadelphous;* in the Tutsan (Hypericum), they grow into several parcels, and are called *polyadelphous.* In common Groundsel (Senecio vulgaris), Lobelia, and many others, the anthers unite to each other by their edges, and are called *syngenesious.* And in Birthwort (Aristolochia), and the Orchis tribe, anthers, filaments, styles, and stigmas become all consolidated and confounded in one central body, named the *column;* plants with this remarkable structure are said to be *gynandrous.*

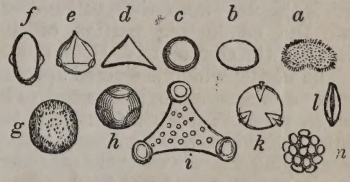
In addition to adhesions of this sort, there is another class, of which great use is made in systematic botany. In the normal state of a flower, the stamens arise from the angle formed between the base of the calyx or corolla, and the ovary (*fig.* 53, *a*), and are then said to be *hypogynous;* but in the Plum, the stamens grow by their lower end to the side of the tube of the calyx, only separating from it at the line where the petals arise; they are then called *perigynous* (*b*); and in the Myrtle they not only grow thus to the side of the tube of the calyx, but also to the face of the ovary, and join those two parts into one body: from this cause they look as if they grew upon the top of the ovary, and are said to be *epigynous* (*c*).

Fig. 53.



Pollen.—The pollen (*fig.* 54), which to the naked eye looks like very fine dust, is the most curious and most varied part of vegetation. It consists of a prodigious multitude of little grains, whose figure is generally uniform in the same species, but which have some hundred modifications of form in different species, and which vary in size from the $\frac{1}{30}$th to the $\frac{1}{240}$th of a line in diameter. Most of their forms are reducible to the spheroidal and the triangular, but some are oval, as in the majority of Umbelliferous plants (*fig.* 54, *l*), and others polyhedral, as in some Compound flowers. The grains of pollen are most commonly single, but in many Acacias they are clustered in little round balls (*m*), and in Orchideous plants in threes or fours; their surface is for the most part smooth, but many are hairy or bristly, or covered with little tubercles symmetrically arranged. Occasionally there are circular spaces upon the surface which open like little lids when the contents of the pollen-grain are discharged, as in the Passion-flower (*h*).

Fig. 54.



In some species, such as many of the Orchis tribe, and all Asclepiadeous plants, the pollen falls in mass from out of the anther, the grains adhering to one another in different ways. In the Orchis, they are collected into wedges, which stick to a central elastic thread; in Neottia they are joined imperfectly in threes and fours, and united by an elastic web; and in Malaxis they form a solid, homogeneous substance, of a waxy texture. In Asclepiadeous plants they are collected within a bag which appears to be the lining of the anther separated from the valves.

The shell of the pollen-grain seems from the best modern authorities to consist of two layers, the external thick, fleshy, and cellular, the internal very thin, membranous, and extensible. Of these the external has often apertures at its angles through which the inner membrane projects in a slight degree, from which cause the angles appear semi-transparent when the pollen is magnified and viewed in water by transmitted light. In those cases in which only one membrane is present, it is said that it is the interior, and that in such instances no trace of aperture is visible.

The structure of the pollen, in consequence of the excessive minuteness of the parts, is not to be seen without much difficulty; but Dr. Fritzsche, a young Prussian botanist, has lately

shown that it may be observed with greater facility than was before supposed by examining the grains in a liquid composed of two parts of concentrated sulphuric acid and three parts of water. By this means, the external coating of the pollen is rendered transparent, the matter within it is coagulated, and partially forced out through the apertures, in the form of long intestine-like sacs, which are called *pollen-tubes*. This phenomenon occurs spontaneously when the grains of pollen have fallen for a few hours upon the stigma, and it is through such intestine-like sacs that the fertilizing matter is ejected from the pollen-grain into the conducting portion of the tissue of the stigma.

The matter which is ejected appears, under a microscope of low power, to be merely a turbid fluid, denser than the water into which it is discharged; upon magnifying glasses of sufficient power being applied, the turbid fluid is found to consist of oblong particles about the $\frac{1}{30000}$th of an inch in diameter, and spheroidal molecules varying in size from the $\frac{1}{150000}$th to the $\frac{1}{33000}$th of an inch in diameter, according to the computation of Mr. Dollond. These, when floating in water, are in active motion, each revolving upon its own axis, and the larger kind having often a sort of spasmodic contraction of the side. It is a general belief that these larger particles are the rudiments of embryos, and that the effect of fertilization is to convey one of them into the ovule; but there is not, and probably from the nature of things never can be, any proof of the correctness of this opinion. Fritzsche, however, asserts that the particles are nothing but grains of amylaceous matter, or globules of oil, and denies their having anything to do with fertilization. It may, however, be observed, that supposing them to be grains of amylaceous matter, yet as they are of definite and regular form, and have a specific motion, it is by no means improbable that nature may have destined them to perform the important action that is ascribed to them. Amylaceous matter, in a dead state, ought not to be confounded with the same substance imbued with the living principle, which takes it beyond the ordinary laws of chemical action, and gives it powers of a special nature. Nor is it to be admitted that the particles of the pollen-fluid cannot be destined to act as a fertilizing power, because grains apparently of the like nature taken from parts having no fertilizing action, will move, as it were, spontaneously when suspended in water; as, for instance, the particles of which the ovary of wheat consists. For in bodies so infinitely small as those in question, nothing is revealed by the microscope beyond their external form, and no one can say that bodies which seem under the microscope to be identical, would not, in fact, be found to be entirely different if it were possible to perceive their structure more distinctly.

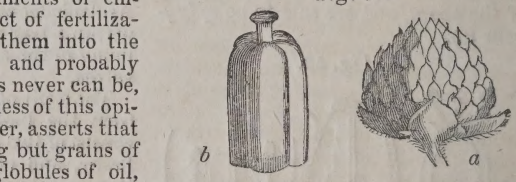
Chapter XVIII.

Of the Pistil, or Fructifying System.

The fructifying system, or *gynæceum*, occupies the centre of a flower, and is the part round which all the other parts are arranged; it is generally called the pistil.

The pistil consists of certain component parts called *carpels*, which are either distinct from each other, as in the Strawberry (*fig.* 55, *a*), or all grown together into one body, as in the Rhododendron (*fig.* 55, *b*); or if the pistil consists of but one carpel as in the Cherry, then the terms pistil and carpel have the same meaning.

Fig. 55.



A carpel consists of *ovary* and *ovules*, *style* and *stigma* (*fig.* 56). The ovary is the lower portion (*fig.* 56, *b*), which is hollow, rounded at the back next the calyx, and sharp at the opposite edge, within which is a double line corresponding with an external suture, and called the *placenta*. The ovary tapers upwards into a slender horn or thread, called the *style*, and on the point of that organ there is a humid space, destitute of cuticle, and usually a little, sometimes very much, distended, which is the *stigma* (*a*). Of these parts the ovary and stigma are present in all carpels, but the style is not more essential than the footstalk to the leaf.

Fig. 56.

The part from which the ovules originate, consisting of an excrescence, more or less considerable, of the united edges of the carpel, is what has been called the *placenta*. Sometimes it bears but a single ovule, more frequently two, and generally a greater number; in many cases it is scarcely visible except in consequence of the ovules growing out of it, but most commonly it has distinctly a fungous appearance, and very often is of considerable size, as in the Primrose and the Lychnis dioica. We shall see, as we proceed, that it is an organ of great importance.

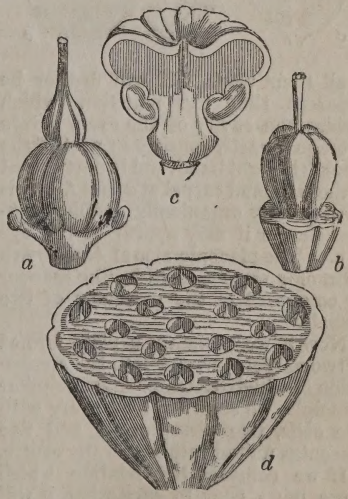
All the principal modifications of pistil with which we are acquainted are produced by the various modes in which the carpels are joined or arranged, or by the state of the growing point round which they are placed.

When one carpel only is present, as in the cherry, the pistil is *simple*; but if more than one carpel is found in the same flower, it is *compound*. Supposing its constituent carpels to be separate from one another either entirely, or to a considerable degree, the pistil is called *apocarpous* (*fig.* 55, *a*), as in the Crowfoot (Ranunculus), the Rose, the Aconite, &c.; but if the carpels grow completely together, the pistil is *syncarpous*, as in the Arbutus, the Lilac, the Chickweed, &c. (*fig.* 55, *b*).

In the disjoined state of the carpels, there are few states of the pistil that deserve to be pointed out, except such as result from an enlargement or hardening of the growing point round which the carpels are placed.

The nature of the growing point in a leaf-bud has been already explained; see page 19. In a flower-bud it has usually no power of extension; for the act of forming the floral organs seems in general to paralyze the central tissue, and to render it incapable of further development; and consequently the carpels are usually the absolute termination of the axis of growth. But in some cases, after the carpels are formed, a partial tendency to develop is manifest, and the central substance rises up between the carpels, disjoining them, and sometimes extending far beyond them (*fig.* 57, *c*). Thus in the Strawberry this power of extension produces a succulent receptacle, which bears the carpels scattered over its surface; in the Geranium it projects beyond the carpels, growing to their styles in the shape of a hardened beak; in the Rue it forms a central column, which is not very visible till the fruit is ripe; and finally in the Nelumbium (*fig.* 57, *d*) it rises up about the carpels, and forms a sort of hemispherical disk in which they are immersed. When it is succulent and belongs to a greater number of carpels than five, it is called *torus*, or receptacle; but when it has five carpels, or a smaller number, placed regularly round it, and finally separating from it, and from each other, when ripe, it is called a *gynobase* (*fig.* 57, *a b*).

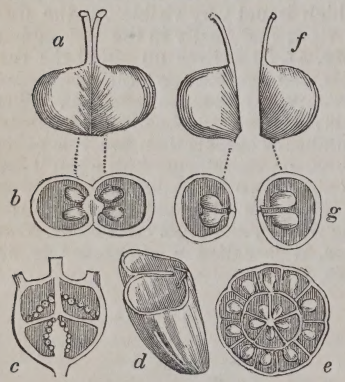
Fig. 57.



An idea of the manner in which the appearance of the pistil is modified by the number of carpels that form it by their union, will be best obtained by

first considering the effect of two being completely combined. Let *fig.* 58, *f*, represent two carpels placed opposite each other, but distinct, each having its own style and stigma; then the *fig.* *g* will represent the appearance of a transverse section of them, with the two placentas pointing towards each other. Also let *fig.* 58, *a*, represent a pistil formed of two carpels combined, and *b* the transverse section of the same. It will then be obvious that the style and stigma of *a*, although apparently simple, are, in fact, composed of two styles and two stigmata grown to each other throughout their whole length, and that the ovary of *a* is in like manner made up of two ovaries complete

Fig. 58.



in all their parts. It will further be apparent that the partition which divides the cavity of the ovary *b* into two equal parts, consists in part of the face of the right hand, and in part of that of the left hand carpel at *a* and *f*, and is consequently organically double, however simple it may appear to the eye to be. The placenta also at *b*, although seemingly simple, must in like manner be composed of the placentas of two carpels.

Now if we exchange a pistil formed of two carpels for one into the composition of which five enter upon a similar principle, we shall have an ovary with five cells, five dissepiments, and five placentas united into one in the centre.

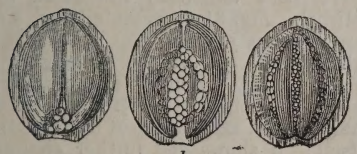
If we consider the relation which these parts bear to each other, it will be apparent that as the dissepiments are formed by the sides of carpels, and as the stigmata are the termination of the backs of the latter, the stigmas must of necessity be placed in all cases of normal structure between the dissepiments, or alternate with them. Hence it is an axiom in structural botany that no partition in an ovary is a genuine dissepiment, unless it bears this relation to the stigmata, and that all others are spurious; and moreover, that all true dissepiments must radiate from a common centre in a direction parallel to the stalk of the ovary. So that such vertical partitions as are met with in the ovary of Amelanchier and Astragalus, proceeding from the back or front of the cell, opposite the stigma, or as occur horizontally in the fruit of Cathartocarpus fistula, are not called dissepiments, but have the technical name of *phragmata.*

The only exceptions that can possibly occur to this law of the relation borne by the dissepiments to the axis and to the stigmas, is in cases where more rows than one of carpels grow together. When this happens *upon the same plane*, the outer row grows by the placentiferous face of each carpel to the back of the carpels of the inner row, as at *fig.* 58, *e*, and then new dissepiments are produced *at right angles* with the common radiating ones. But if two rows, which arise from two different planes, adhere to each other, the position of the parts will become, as at *fig.* 58, *c*, so oblique, that genuine horizontal dissepiments will be the result. This has been shown by Dr. Lindley to be the explanation of the curious structure of the Pomegranate.

Although, from what precedes, it would seem to follow that all pistils consisting of more carpels than one grown together should contain cells separated by true dissepiments, yet this rule is sometimes deviated from in consequence of certain special modifications of the usual manner of growth. Suppose the constituent carpels of a syncarpous pistil not to be closed up at the edge which bears the placentæ, but to be partially opened, and yet to grow together where they touch; they would, in such a case, form what is called a one-celled pistil, with *parietal* placentæ (*fig.* 59, *a*), in which the sides of the carpels only project from the inside of the pistil into its cavity, without meeting in the centre: this happens in the Poppy, and many other plants. Or it may occur that a pistil, originally of the most normal structure, may assume an anomalous ap-

pearance after a certain period, in consequence of an inequality in the rate at which its different parts may grow. Thus, in what are called Caryophylleous plants, such as the Lychnis dioica, the Mouse-ear chickweed (Cerastium), &c., the pistil, when very young, has several cells, separated by complete dissepiments, and joining in the middle by their respective placentas. But after a time the dissepiments lose all power of growing, while the placentas expand, and the shell of the ovary increases steadily in dimension; in consequence of this the dissepiments are ruptured by the opposing strain of the placentas on the one hand, which will not separate, and of the shell of the ovary on the other, or, in other words, of the back of the carpels, which are compelled to spread away from the centre by the addition that is constantly making to their dimensions in every direction; the circumference of such a pistil is perpetually pulling against the centre, and as the dissepiments will neither grow nor stretch, they must necessarily be rent in twain (*fig.* 59, *b*). From this results—1. if the placentæ grew along the whole length of the inner edge of the carpels, a *free central placenta*, as in Lychnis (*fig.* 59, *b*); or 2. if they appeared only at the base of the inner edge of the carpels, a *free basal placenta*, as in the Tamarisk (*fig.* 59, *c*).

Fig. 59.



c *b* *a*

Instances of this kind serve to show the student of botany, that the most singular anomalies of structure are susceptible of easy explanation if attention is steadily fixed upon first principles; and that it is highly unphilosophical to suppose that the simplicity of design which is so generally manifested in the works of nature, is departed from in certain special cases, merely because we may be unable rightly to understand them without reflection.

There are few modifications of the *style* which are worth noticing, except such as are caused by its distension in one direction, when it becomes petal-like, or in all directions when it is club-shaped and massive. In the Iris is one of the most remarkable instances of its assuming the appearance of a petal; and Indian shot (Cauna) affords another. In Asclepias, Stapelia, Tupistra, and others, it becomes succulent, and acquires a fungus-like appearance.

The *stigma* is subject to similar alterations, but in a much less degree, and it is probable that many anomalous forms referred by botanists to the stigma really belong to the style. Some of its most singular states are the following:—in Rhubarb (Rheum) it forms three flat orbicular disks, in Dock (Rumex) as many fringed round tassels, and in Grasses a tufted hairy body like the brushes with which holy water is scattered about in Catholic churches. In the Poppy the stigmas collect into a star-like body, crowning the top of the ovary; in the Heart's-ease it is a hollow globe with a small aperture on one side; in the Monkey flower (Mimulus) it consists of two membranous lips which have the power of contraction when irritated, and in Clarkia it consists of four broad white petal-like lobes. In Orchideous plants it is an oval humid space hollowed out of the face of the central column of those plants, and in general it has a surface which is covered with a clammy or gluey secretion; this is no doubt a provision for enabling it to retain the pollen grains when they fall upon it; when it has not such a contrivance, it is covered over with long finger-like processes, in which the pollen is entangled, as in Grasses, &c. There are, however, some plants in which the surface of the stigma is undistinguishable from that of the style, as in Birthwort (Aristolochia), Asclepiadeous plants, and Tupistra.

Generally the stigma is undivided, and consequently the number of stigmas indicates the number of carpels of which a syncarpous pistil consists. But this mark is not always to be trusted; for in most Euphorbiaceous plants the stigma of each carpel is divided into two deep lobes, and in Grasses, the pistil of which is perfectly simple, there are uniformly two stigmas some distance apart at the base. It is important that this should be well considered by those who are engaged in the study of vegetable structure; for it will sometimes offer an easy solution

of what may at first appear a most difficult problem. For instance, Cruciferous plants have their stigmas apparently opposite the placentas; Dr. Lindley has attempted to explain this away by assuming that the structure of the pistil of such plants is in reality much more complicated than it seems to be; but Dr. Brown, on the contrary, finds a simpler and apparently a more probable explanation in the original two-lobed structure of the stigma of Cruciferæ.

Chapter XIX.

Of the Ovule.

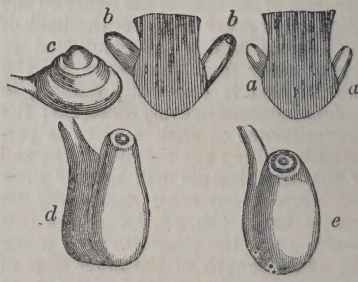
To the naked eye the ovule is an oval grain with a mother-of-pearl colour, and seems, when crushed, to be simply a bag of gelatinous matter; but in reality it is an organ whose structure is by no means so simple. It consists of a central part called the *nucleus*, over which are placed one, two, three, or four membranes, called from their position the *primine*, *secundine*, *tercine*, and *quartine*, the primine being the most external. All these are pierced, at the part which corresponds with the point of the nucleus, with a hole called the *foramen* (*fig.* 60, *a*), so that the point of the nucleus is freely exposed to external influence. It is believed that the

Fig. 60.

fertilizing influence of the pollen, of whatever nature it may be, is here introduced; for it is uniformly found that the rudiment of an embryo first appears at the point of the nucleus; and, in fact, the foramen of the ovule may be taken with perfect confidence as the situation of the future radicle of the embryo; a point of no inconsiderable importance in systematic botany. Although the ovule is in some cases furnished with the four integuments just mentioned, to which a fifth, the *quintine*, or immediate coat of the nucleus, has to be added, yet in the majority of cases the primine, secundine, and tercine are all that can be detected, and even one of these is absent in the Alder and its allies, whose ovules have only a primine and a coat to the nucleus. These facts have been elucidated chiefly by the careful investigations of Brown and Mirbel.

The situation of the foramen is always at a very early period of the growth of the ovule at the apex; and in many ovules it subsequently remains there; but in the majority of plants the ovule bends down upon itself, and gradually brings its apex down to its base, when the foramen becomes con-

Fig. 61.



tiguous to the point of insertion of the ovule. This is particularly well seen in the gourd tribe, whose changes from a very early state, when the ovule is a mere pulpy tubercle, to its perfect condition, are easily followed, and have been admirably illustrated by Mirbel. *Fig.* 61 represents this: *a a* are two very young ovules in their original state; *b b* are the same grown older, with the foramen just appearing; *c* is one of them with its three coats fully formed and half bent down upon itself; *d* shows the further change when the ovule has actually become inverted in consequence of the bending down being accomplished; and *e* represents the ovule in its perfect state, when ready to be fertilized.

It appears probable that the different stations of the foramen upon the surface of the ovule are closely connected with the peculiar manner in which, from the structure of other parts, the phenomenon of fertilization takes place in different species of plants

The position of the ovule, with regard to the ovary, is *erect* when it rises from the very base of the cavity; *ascending* when it originates a little above the base; *pendulous* when it hangs from

the very apex; *suspended* when it is hung up as it were from a little below the apex; and finally, *horizontal* or *peltate* when it is attached by its middle to the middle of the placenta.

Further, ovules are said to be *definite* when their number is uniform and easily counted; and *indefinite*, if their number is uncertain and too great to be correctly counted.

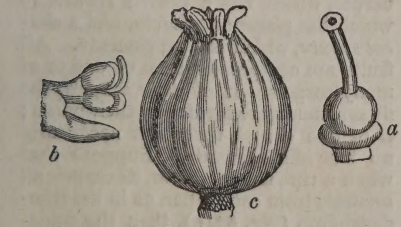
Chapter XX.

Of the Disk.

This name is given to a body which arises from the base of the ovary in the form of a ring, or of scales, or glands, or of a sort of cup. It is almost always fleshy, and seems in most cases to secrete honey.

In the Orange, it is a yellowish fleshy ring (*fig.* 62, *a*); in the alpine Scullcap (Scutellaria) (*fig.* 62, *b*), it is a thick scale placed on one side of the ovary; in the Mignionette (Reseda), it is a broad hairy plate, out of which the ovary arises; in Grasses it is two minute hypogynous scales; in the tree Pæony it is a purple cup, which covers the pistil all over except the stigmas (*fig.* 62, *c*); and in the Cherry it forms a thick shining lining to the tube of the calyx. Besides which, it is found under other forms.

Fig. 62.



It is probable that this organ is, in all cases, a rudimentary state of some undeveloped stamens; and that it is altogether of a different nature from the torus (see p. 43) with which it is generally confounded. That such is its real nature, seems to be proved by these circumstances: that in some Meliaceous plants, such as Turræa pinnata, it is exactly like an external cup, which bears the stamens, and is manifestly produced by the juncture of their filaments; that in Scitamineous plants its parts occupy the place of certain stamens which are not to be found in the place where they ought to be stationed in a case of regular structure; and that in the tree Pæony it has actually been seen with an anther growing upon it.

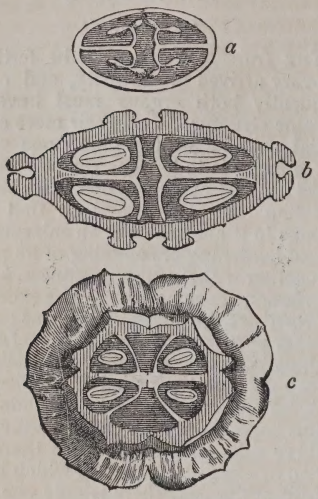
Chapter XXI.

Of the Fruit.

The fruit of a plant is the fertilized ovary arrived at maturity, and consequently both organs must have the same structure in all their more essential points; for the plan upon which the ovary is to be constructed is finally determined at the period when fertilization takes place, and all that happens to it afterwards is an enlargement and hardening or softening of its parts, together with, in some instances, a suppression of one portion by the excessive growth of the adjacent portions; or in other instances by the addition of something which only existed in a rudimentary state at the period of fertilization. A few instances will serve to show how this happens. In the Oak the ovary has three cells, in each of which there are two ovules; in the acorn, which is the fruit of the oak, there is only one seed and one cell: here two cells and five ovules are destroyed by the exclusive growth of one ovule. In the ovary of the Sweet chestnut (Castanea) there are seven cells with two ovules in each; the ripe fruit consists of but one cell and one seed, so that in this instance no fewer than six cells and thirteen ovules are suppressed, in order to enable a single ovule to grow and be matured. Another common instance in which a variation exists between the ovary and the mature fruit, but from a different cause, occurs in the genus Astragalus, of which the ovary is absolutely one-celled, but the fruit two-celled; an extension of the back of the cell, subsequent to fertilization, projecting forward into the cavity, and touching the placenta, is the cause of this. But one of the most remarkable deviations from original structure has been described in the *Botanical Register*, t. 934, in the fruit of a genus called Martynia. The author says that its fruit had been always described as four-celled, but that upon a careful examination of the ovary, it will be found that the fruit, in that stage (*fig.* 63, *a*), is neither four-celled, nor even two-celled, but consists of only one cell, traversed by two projecting parietal placentæ, each of which is two-lobed, the lobes dividing at right angles from their point of separation, and

bearing on their edges a few horizontal ovules, of which part project into the open centre of the ovary, and the others

Fig. 63.



into the cavity between the placenta, and the lining of the ovary. Now, the fruit (*fig.* 63, *b*) differs from the ovary in no essential point of structure; but the following changes take place: the shell of the ovary and the placentas become hard and woody; the inner faces of the latter become pressed together, so as to destroy the ovules which were placed between them, and to exhibit the appearance of a dissepiment of two plates; and the remaining ovules become pendulous and reduced in number, mature in the form of large wingless seeds between the inner edge of the lateral lobes of the placenta and the shell of the fruit. To this we may add that in a genus called Pretrea, nearly related to Martynia, the lateral lobes of the ovary actually grow to the shell where they touch it (*fig.* 63, *c*), and to each other in the middle, so that an ovary of one cell becomes changed by adhesions into a fruit of six cells. These, and there are multitudes of similar instances, ought to teach the young botanist never to hope to understand the true structure of the fruit of a plant, without having recourse to the anatomy of its ovary; for plants are perpetually in a state of masquerade, which, to the eyes of those who do not know the value of a rigid observance of first principles, must be impenetrable.

Having premised thus much concerning the general nature of the transitions from ovary to fruit, we proceed next to some observations upon the normal condition of the latter organ.

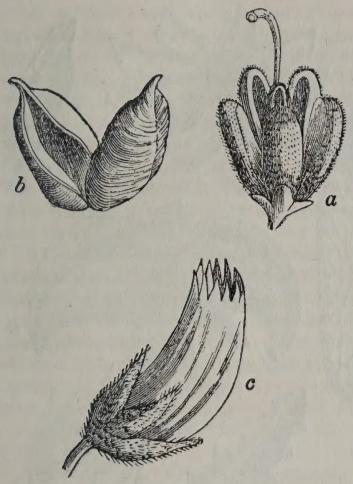
Its shell is what botanists call the *pericarp;* this part is usually homogeneous, but in some plants is not so. In the Peach, for example, the outside is a thin membrane, which may be easily peeled off: it is called the *epicarp;* then comes a quantity of sweet pulpy matter which we eat: that is the *sarcocarp;* and finally there is a hard bony wrinkled part called the *stone* by the vulgar, and the *endocarp* or *putamen* by the botanist. These distinctions are important in describing plants, because descriptions often require that not only all parts, but all modifications of parts, should be indicated by special names.

Some fruits are always closed up to the latest hour of their existence, as the cocoa-nut; others have the property of bursting into separate pieces or *valves* when ripe, as the lilac. This act of bursting is called *dehiscence,* and its varieties are often of material importance in distinguishing plants from each other. We must therefore state what are the typical forms of dehiscence. But for this purpose we must revert to the original structure of the pistil.

A simple pistil is composed of a single carpel, which has a *ventral suture,* to which the placenta adheres, and a *dorsal suture,* which has no placenta. All fruits are composed either of one or of many carpels. If of many carpels, the dissepiments are formed by their union; if of one carpel, there are necessarily no true dissepiments. Suppose that when a ripe fruit dehisces, its carpels all separate from each other, as in the Rhododendron (*fig.* 64, *a*), then the dehiscence is called *septicidal,* and the fruit is resolved into its original elements; but if the carpels refuse to separate and give way only by their dorsal suture (*fig.* 64, *b*), then the dehiscence becomes *loculicidal,* as in the Lilac. These two cases are the most common, and the only ones which are worth naming, as instances of a regular manner of dehiscing; and almost all others are reducible to such types. When, for example, a fruit is said to burst by valves at its point (*fig.* 64, *c*), as in the Mouse-ear chickweed (Cerastium), a partial separation of the carpels takes place both at their dorsal sutures and between

each other, just at the end of the fruit; and in the Palma Christi (Ricinus), and many other plants, a sort of compound bursting occurs; first of all, the carpels separate from each other, and septi-

Fig. 64.



cidal dehiscence is the result; then each carpel splits by its two sutures: this is loculicidal opening; and finally, the shell divides into two layers (the sarcocarp and endocarp), which contract and separate from each other with some force

There are, however, some irregular forms, which are too curious to be passed by in silence, as they are not reducible to either or any of the two foregoing types. The Poppy (*fig.* 65, *d*)

Fig. 65.

discharges its seeds by a number of little openings which lie below the rim produced by its broad peltate stigmas; the Snapdragon (Antirrhinum) (*fig.* 65, *a*) has similar openings near the apex of its fruit; and the Blue-bells (Campanula) burst by ragged holes at the bottom of their capsule (*fig.* 65, *c*, &c.). The Spirting cucumber (Momordica elaterium) discharges its slimy pulp and seeds by ejecting them violently through the place where the fruit and the peduncle are joined, forcing out the peduncle like a plug from a barrel of fermenting liquor. The Primrose, and many others, bear fruit which opens by a transverse separation of the shell into two parts (*fig.* 65, *b*), the upper looking like a cap to the under; and the Bird's-foot trefoil (Ornithopus) has pods which break across into a number of joints. Finally, in most Cruciferous plants the valves of the fruit drop off a *frame* (*replum*), to which the seeds adhere, and which seems formed by a junction of the sutures.

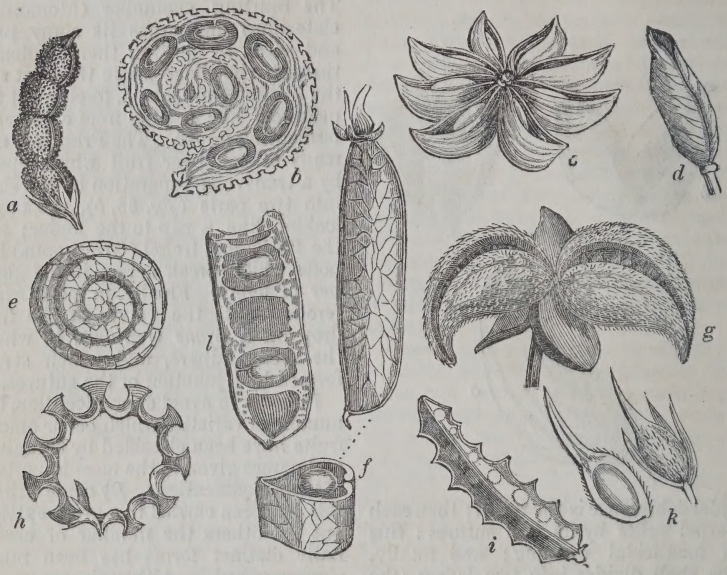
In order to avoid circumlocution, the numerous varieties which occur among fruits have been classified by botanists, and names given to the most important of their modifications. By some writers this has been carried to a great extent; but by others the number of essentially distinct forms has been much circumscribed. Although for many purposes, especially for arranging a carpological collection, the more exact definitions of the former deserve to be adhered to, and consequently their nomenclature adopted; yet it must be admitted, that for the common purposes of descriptive botany, a very small number of terms is sufficient. No others will therefore be admitted into this sketch than such as are of every-day occurrence in the writings of botanists.

The *follicle* (*fig.* 66, *d*) may be considered as a carpel in its ripe state, opening by its ventral suture only, and consequently to be typical of all modifications of fruit, as the carpel itself is of all modifications of pistil. Instances of a solitary follicle are found in the Larkspur (Delphinium), and of several in the same flower in the Pæony, the Star anise (Illicium) (*fig.* 66, *c g*), and many others.

From the latter, botanists distinguish the *legume* (*fig.* 66, *f*), which is, however, hardly susceptible of a definition, so various are the forms under which it occurs. Its most genuine state is as we find it in the Pea where it is a

follicle opening by both dorsal and ventral sutures into two valves. But it is often incapable of opening, and then is only to be known by the distinct double suture which runs round it. In this state it is sometimes divided into a great number of cells, each containing one seed, and formed by hori-

Fig. 66



zontal partitions arising from the lining of the shell (*fig.* 66, *l*), as in Tetragonolobus and the Carob tree (Ceratonia); or it may be precisely like a common legume, except that it does not open; or it may be reduced to a single seed, as in Clover, Psoralea, &c. (*fig.* 66, *k*). But its most singular appearances take place when the shell contracts round the seeds, so as to look as if it consisted of a number of distinct joints; in the Sawpod (Biserrula) (*fig.* 66, *i*) it is compressed from the back to the front, and is deeply and regularly scalloped at each edge; in Horseshoe-wort (Hippocrepis comosa) (*fig.* 66, *h*) it is compressed laterally, and one side only is scalloped; in the French honeysuckle (Hedysarum coronarium) (*fig.* 66, *a*) it is simply contracted, and eventually falls into pieces, each of which contains a seed; in the Caterpillar plant (Scorpiurus) it is rolled up upon itself, and covered with tubercles (*fig.* 66, *b*); and finally, in the Snail-plants (various species of Medicago), the convolutions are extremely like those of some univalve shells (*fig.* 66, *e*). Such legumes as separate transversely into distinct pieces are sometimes called *lomenta*, or *lomentaceous*

The *achenium*, or grain (*fig.* 67, *b*), is a carpel which is one-seeded, does not open when ripe, and has no suture at all. It is what the old botanists called a naked seed, because it resembles a seed in size and texture. Instances of it occur in the Strawberry, the Crowfoot, and the Fig, in which what are popularly called the seeds are the *achenia*. Sometimes this kind of fruit is terminated by a kind of plume (*fig.* 67, *a*), as in Virgin's bower (Clematis), which is the hardened style covered over with long feathery hairs; or it is crowned by a number of scales or hairs called *pappus*, placed in a ring at its summit, as in Compound flowers (*fig.* 67, *c d*). Two achenia combined form the fruit of an Umbelliferous (*fig.* 67, *g*) plant, and two or four, united at their bases only (*fig.* 67, *e*), that of a Borageineous one.

A *cariopsis* is an achenium with a thin shell, which grows so close to the skin of the seed as to be inseparable and undistinguishable; such is the

fruit of Wheat, Maize, and other kinds of corn.

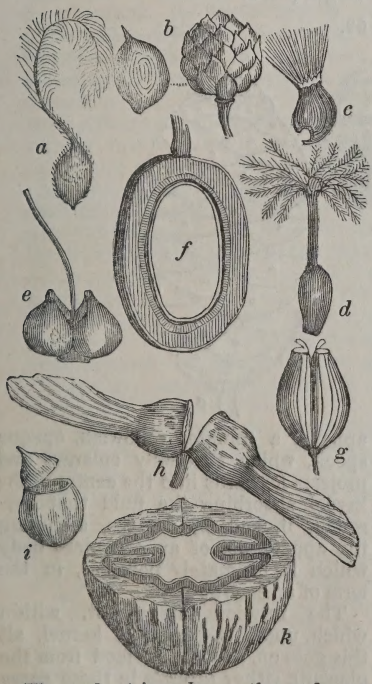
A *utricle* is a cariopsis with a thin loose shell; it would be an achenium if the shell were hard; it occurs in Goosefoot (Chenopodium), and often divides transversely (*fig.* 67, *i*).

A *nut* is an achenium in every thing, except that it results from a compound pistil, and is really composed of several carpels, although all of them may be abortive except one. The Hazel-nut, the Chestnut, the Acorn, are familiar instances of this.

The *key* (Samara) is either an achenium, or a nut with the summit expanded into a wing, as in the Ash and the Sycamore (*fig.* 67, *a*).

The *drupe* is an achenium with the shell separable into two layers, of which the inner is hard and bony, forming a *stone* or *endocarp*, and the other soft and juicy, forming a flesh. The fruits of the Peach, the Plum, the Cherry, are drupes (*fig.* 67, *f*).

Fig. 67.



The walnut is a drupe, the endocarp of which separates into two valves, each of which has an imperfect spurious dissepiment projecting from the back, and cutting the seed into deep lobes (*fig.* 67, *k*).

The *berry* (bacca) is composed of several carpels, which, when ripe, are a mere mass of pulp, in which the seeds lie buried, as the Grape and the Gooseberry.

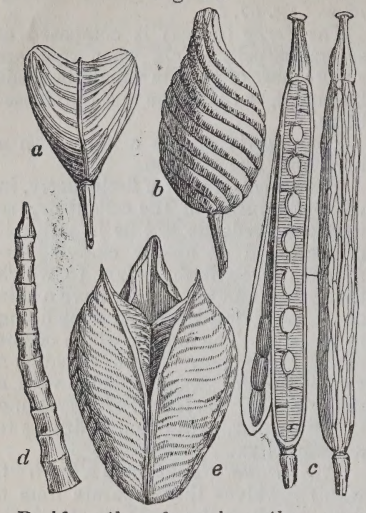
The *gourd* (pepo) is a berry with a hard rind, like a Melon.

The *pome* is a sort of fleshy berry, in which the inside of the cells is dry, so that the seeds do not lie in pulp; it is composed of a few carpels surrounded by a fleshy calyx, to which they grow, and may either have a thin and papery, or a thick and bony lining to its cells. The former, which occurs in the Apple, may be considered as a combination of fleshy follicles with a fleshy calyx; the latter, which we find in the Medlar, as a union of drupes to a fleshy calyx.

The *siliqua* (*fig.* 68, *c*) is a dry fruit, with two valves that separate from a frame to which the seeds are attached: in the Cabbage it is long and narrow; in the Shepherd's purse (Capsella), it is short and broad (*fig.* 68, *a*); the latter is called a *silicle;* in Sea-kale, the valves do not separate from the frame.

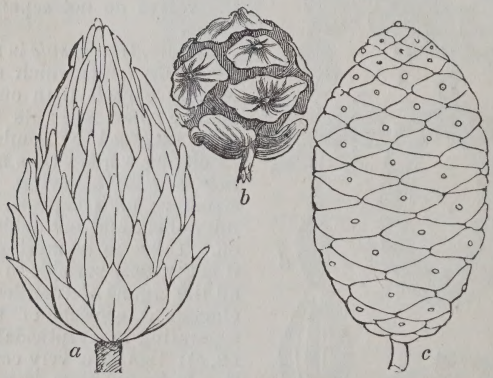
Finally, the *capsule* is a general term for all dry fruits which are composed of more carpels than one, and which dehisce when ripe; its application is even extended by combining it with modifying words; thus a *berried capsule* is a fruit having the ordinary structure of a capsule, with a soft, juicy shell, and not dehiscing; and so on. Taken in its most general sense, it is the most variable in appearance of all the organs of fructification. In Colchicum it consists of three follicles separating in a septicidal manner (*fig.* 68, *e*); this is a very common form of it. In Snapdragon, it consists of two cells opening at the summit by three pores (*fig.* 65). In the Sun-tree (Heliocarpus), it has two cells, opening in a loculicidal manner, and surrounded by long feathery processes which give it the appearance of a Catholic glory. In Hypecoum it is long, taper, curved, and separates into one-seeded joints like a lomentaceous legume (*fig.* 68, *d*), from which it is known by its seeds being attached to *both* sutures. In the Screw-fruits (Helicteres) it consists of five slender, narrow follicles, which are twisted together in a most remarkable manner (*fig.* 68, *b*).

Fig. 68.



Besides the foregoing, there are several fruits which are not produced by single flowers, but which are formed by the adhesion of a considerable number of flowers into a single mass. Such is the fir-cone, each of whose scales represents a single flower (*fig.* 69, *c*); the pine-apple, which consists of as many flowers as there are rhomboidal spaces upon its surface; and the mulberry, each of whose tubercles represents a single flower. These may either be all considered as varieties of the *strobilus* or cone; or with some others may be looked upon as forming a section in a methodical arrangement of fruits, in which latter case they would have several different names. It is more conformable to the plan of this treatise to take the first view of them; for an explanation of the other, the reader is referred to *Lindley's Introduction to Botany*, in which this subject is treated in detail. True cones (*fig.* 69, *b c*) must not be confounded with such aggregations of carpels as we find in the Magnolia (*fig.* 69, *a*), which are like cones in appearance, but which, in reality, are the result of the growth of one single pistil.

Fig. 69.



Chapter XXII.

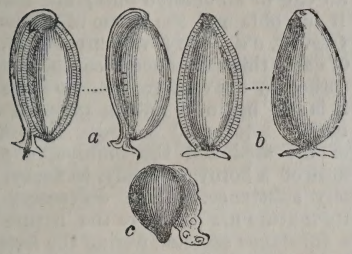
Of the Seed.

While changes are coming over the pistil subsequent to the discharge upon the stigma of the fertilizing principle of the pollen, the ovules are also undergoing a metamorphosis still more interesting and important. No sooner has the mysterious influence of the pollen been introduced into the ovule, than its foramen closes up, its integuments extend and harden, the pulpy substance within them consolidates, and in the midst of the latter, within the kernel, close to the foramen, there appears a minute, yellowish, opaque speck, which gradually enlarges and projects forwards into the centre of the kernel, absorbing the fluid that surrounds it, and, by degrees, assuming the appearance of an organized body which it ultimately becomes, in the form of an *embryo* plant.

The interior integument, within which, under the name of kernel, all this goes on, absorbs its food from the placenta either *directly* in those cases in which, the foramen being at the summit of the ovule, the base of the kernel is next the placenta (*fig.* 70, *b*), or indirectly by means of a cord of

vessels which expand at their termination in those cases in which the foramen is at the base of the ovule (*fig.* 70, *a*); in the latter case, the

Fig. 70.



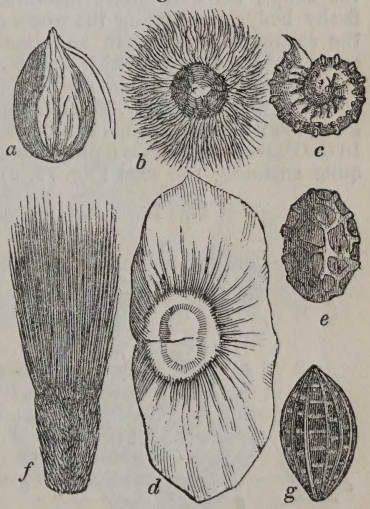
cord of vessels is called the *raphe*, and their expansion, which corresponds with the base of the kernel, the *chalaza*. It will, therefore, be obvious, that where a raphe and chalaza are present, the kernel is inverted, and where they are absent, it is erect; a fact of considerable practical value. This may, indeed, be made out by two other means, either by discovering the foramen, which, in the ripe seed, is sometimes called the *micropyle*, or by dissection; but both these modes are more difficult of application than ascertaining the presence or absence of a raphe and chalaza. Now it has been previously stated (p. 46), that the radicle of the embryo is uniformly found next the foramen; and from this and the other facts just recited, two axioms of the greatest practical value in examining seeds are derived. 1. *When there is neither raphe nor chalaza, the kernel of the seed is erect, and the embryo inverted.* 2. *When a raphe and chalaza are present, the kernel is inverted, and the embryo erect.*

When fully formed, the seed separates from the placenta, retaining a scar, called the *hilum* or *eye*, at the spot where the separation takes place. In some seeds this hilum is very minute, in others it extends more than half round the seed in the form of a broad belt, as in the genus Dolichos.

The integuments of the seed, called collectively the *testa*, or skin, are uncertain in number, like those of the ovule, of which they are merely the ripe state. While, however, they may be fewer in consequence of one or more of them disappearing in the course of the transition from ovule to seed, they never can be more numerous. Two integuments are very obvious in the walnut, the outer of which is brown and tough, the inner white and filmy; and a similar structure is apparent in the almond; in the gourd there is a thin exterior skin, a hard intermediate crust, and a fine inner membrane lying immediately upon the embryo; in the two first cases, the primine and secundine only are discernible in the ripe seed; in the third, the tercine also may be separated.

Nothing can well be more beautiful than the marking of the surface of seeds, especially the minuter kinds, nor anything more varied. In the common Almond, the whole surface is regularly veined by ramifications of the raphe (*fig.* 71, *a*): in the Primrose, it is marked with little projecting points; in a Brazilian plant named Physostemon, it is coiled up like a snail (*fig.* 71, *c*); in Snapdragon, it is marked all over with deep impressions (*fig.* 71, *e*); and in the Prickly poppy it is ribbed and barred across like a closely-grated prison window (*fig.* 71, *g*). Of the

Fig. 71.

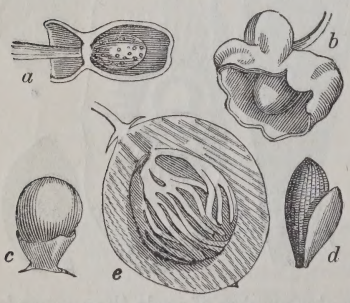


greater number of seeds the surface is perfectly bald, but there are some remarkable for their excessive hairiness: the Cotton-seed, for example, is enveloped in long hairs which grow from every point of its surface, and form the substance so extensively used in manufactures (*fig.* 71, *b*); in the Oleander and similar plants (*fig.* 71, *f*,) the hairs are chiefly confined to one

end of the seed, and appear destined to carry it aloft in the air so as to be conveyed to a distance from its spot of birth. Nor are hairs the only means of transport through the air which seeds possess; some have broad, membranous expansions, called *wings*, the office of which they really seem to serve, as in Bignonia, and plants allied to it (*fig.* 71, *d*).

It frequently happens that seeds are attached to the placenta by a sort of stalk, called the *umbilical cord;* which is an extension of the placenta itself, and consists of a bundle of nourishing vessels surrounded by spongy matter. In its ordinary state, the umbilical cord rarely attracts much attention; but it sometimes assumes a very remarkable appearance. In the common Spindle-tree (Euonymus), the seed is enveloped in a red fleshy bag, which is open at the mouth, and which is an expansion of the top of the umbilical cord just below the hilum (*fig.* 72, *b*). An organ of this sort is called an *aril;* the most remarkable instance of it occurs in the Nutmeg, in which it forms the mace of the shops, being a tough, lacerated, fleshy body, overlapping the whole of the seed (*fig.* 72, *e*): in an almost equal state of development it occurs in the Akee plant (Blighia sapida), in which it forms a fleshy, eatable fungosity, in which the seed is half buried. In the Passion-flower it is a pulpy hood, quite enclosing the seed (*fig.* 72, *a*);

Fig. 72.

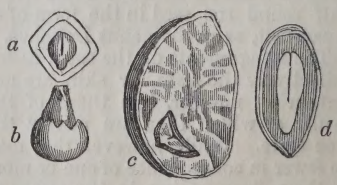


in Heart-seed (Cardiospermum), it is a little plate (*fig.* 72, *c*); and in Turnera it is only a scale standing by the side of the seed (*fig.* 72, *d*). The uses of this organ are unknown; it is however to be remarked that it is never formed until after the fertilization of the ovule has been accomplished.

It has been already stated that the embryo is originally formed in the midst of the pulpy substance of the kernel, and that it is nourished by it during its growth. This pulpy matter bears, apparently, much the same relation to the embryo plant as the white of an egg to an embryo bird; and hence it has obtained the name of *albumen* (*fig.* 73, *c d*). In a very great number of cases this substance is so wholly absorbed by the embryo, that no trace of it is left behind; but in others it remains interposed between the skin of the seed and the embryo, in the form of a horny, or mealy, or fleshy, or oily substance. These differences in its texture are owing to the nature of a substance secreted during the formation of the seed within the cellular tissue of the kernel, and replacing the fluid matter consumed by the embryo; a substance which, in Corn, consists of farinaceous matter adapted for the food of man; in Coffee, of a stimulating secretion, the infusion of which forms a grateful beverage; and in the Poppy, of greasy matter, from which a valuable oil is extracted; but which, in all cases, seems more particularly destined for the nutrition of the embryo in its infant state. If a part only of the cellular substance of the kernel is filled with a solid deposit, and another part remains empty after having been drained by the embryo, the albumen will, in that case, represent a heterogeneous mass, full of irregular cavities, among which solid matter is interspersed, as in the Nutmeg and some other plants. Albumen of this kind is called *ruminated* (*fig.* 73, *c*).

These are generally the only parts of a seed of any importance except the embryo, of which we shall treat in the succeeding chapter. There is, however, in some cases, an additional part called the *vitellus*. In the yellow Water-lily (Nuphar luteum), there is a

Fig. 73.



fleshy bag which intervenes between the albumen and embryo, enclosing the

latter (*fig.* 73, *a*); a similar structure occurs in a few other instances, especially in all species of the Ginger tribe, where it forms a sort of cup, beyond which the embryo protrudes (*fig.* 73, *b*). This part, which is, in reality, the innermost integument of the ovule, in an indurated state, is the *vitellus;* and before the anatomy of the ovule had been made out by Brown and Mirbel, was a very puzzling organ for botanists to account for. Its use is unknown.

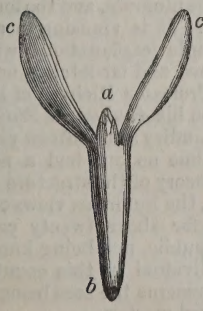
From what has gone before, it is clear that the ovule is the origin of the seed; and as nearly all ovules are originally enclosed within a carpel, there can be no such thing as naked seeds except in a very few instances. What the old botanists called naked seeds were usually achenia; and true naked seeds are hardly known beyond Coniferous and Cycadeous plants; concerning which see the Systematic part of this Treatise.

Chapter XXIII.

Of the Embryo.

This part is so extremely varied in its structure, that it is absolutely necessary to take some one form as typical of the remainder, if the endless modifications it exhibits are to be correctly understood. For this purpose let *a b*, *fig.* 74, represent the central portion or

Fig. 74.



axis of any embryo, and *c c* two *seed-leaves* called cotyledons, growing from it. The part from *a* to *b* will then represent a stem, of which *a*, called the *plumule*, is the growing point; *b*, the *radicle*, is the root; and the intermediate space between the radicle *b* and the base of the cotyledons *c*, an internode: upon which supposition the plumule will be axillary to both cotyledons at once. From this form of embryo all our ideas of that organ may be derived: it represents more particularly what is called a *dicotyledonous* embryo, in which not only there are two cotyledons, but they are opposite to each other; let the number of cotyledons be increased, all other things remaining as before, and it is *polycotyledonous*, as in Fir trees (*fig.* 75, *d*).

In the Lime tree (Tilia) the cotyledons are broad, thin, and leafy (*fig.* 75, *c*); in the genus Ardisia, they are very short, while the radicle is undulated and very long in proportion (*fig.* 75, *b*); in Cactus they are almost rudimentary (*fig.* 75, *e*); in the Horse-chestnut they grow together by their faces into a solid body, enclosing the plumule.

Usually they are undivided, but in the loop-holed Menispermum they are pierced with holes (*fig.* 75, *a*); and in some Cruciferous plants are deeply gashed.

Fig. 75.

Ordinarily they lie flat face to face, but there are many exceptions to this; in the common Maple (Acer campestre) they are folded and plaited something like a bat's wings (*fig.* 75, *g*); in the Pomegranate they are rolled round each other in a spiral manner (*fig.* 75 *f*); in Cordia myxa they are plaited in such a way, that when cut through horizontally, they resemble the quilling round a lady's gown; in the Chocolate plant (Theobroma cacao) they have a broken and most irregular arrangement, forming when within the seed an oblong wrinkled body (*fig.* 75, *h*).

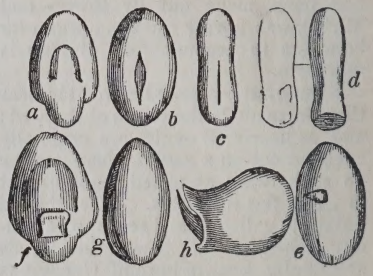
Commonly the embryo is straight or but slightly curved; but in certain

plants it is rolled up in a singular way; in the Chalcedonian Lychnis, and many species of the same natural order, it is *annular*, that is, curved into the form of a ring, the summit of the cotyledons touching the point of the radicle (*fig.* 75, *l*); in the Caterpillar plant (Scorpiurus) it is folded so as to resemble the letter S; and in Dodder (Cuscuta) it is spiral (*fig.* 75, *k*).

All the foregoing modifications are easily intelligible upon reference to the typical form of the embryo; but there are others called *monocotyledonous*, because they have only one cotyledon, in which the analogy between them and the supposed type is at first sight not apparent. Take, for instance, the embryo of a Cocoa-nut (*fig.* 76, *d*); it is a taper fleshy body, somewhat club-shaped at one end, and abruptly blunted at the other; no trace of cotyledon, plumule, or radicle, is externally discoverable. If however it is divided with a thin and sharp knife from top to bottom into two equal parts, it will be found that near the blunt end there is an internal conical tumour directed upwards; this is ascertained by the germination of a cocoa-nut to be the young *plumule;* and this being known, it follows that the abruptly blunted end of this embryo is the radicle, and the other the cotyledon; hence it derives its name of *monocotyledon.*

But although thus much is to be determined without great difficulty, there still remains a want of proof that the so-called single cotyledon is not in fact composed, like that of the Horse-chestnut, of two grown together. The demonstration of this is by a curious series of proofs. 1. The embryo of an Arum is like that of a Palm, only there is a slit on one side of it through which the plumule easily escapes (*fig.* 76, *c*). 2. In Rice (Oryza) this slit is very much lengthened and widened (*b*). 3. In Barley the plumule projects beyond the slit, leaving a flat cotyledon on one side (*a*); and 4. In Wheat the embryo has the structure of Barley, with this most important exception, that at the base of the plumule in front there is a rudimentary cotyledon alternate with the large flat one, on the opposite side of the plumule (*f*). Hence we are to infer that the monocotyledonous embryo of a Palm *is analogous to that of a dicotyledon, of which one of the cotyledons is abstracted, and the other rolled round the plumula and consolidated at its edges.* And this is the view that must be taken of the monocotyledonous embryo in general, all the modifications of which seem reducible to this standard.

Fig. 76.



Thus in Sea-wrack (*fig.* 76, *g*) (Zostera marina) of which the embryo is an oblong almond-shaped body with a cleft on one side, in the cavity of which a long flexuose process is placed, the latter is the plumule, and the former at one end the cotyledon, and the radicle at the other; in Ruppia maritima, whose embryo is an oblong body, cut suddenly off at one end (*fig.* 76, *h*) on which a sort of curved horn crouches, the latter is the plumule, and the former chiefly cotyledon; and so in Frog-bit (Hydrocharis morsus ranæ), the embryo of which is an oblong fleshy kernel with a hole on one side, in which there lies a short cylinder; the latter is the plumule, and the former the cotyledon. It is amusing to compare these simple explanations with the overstrained and far-fetched notions of the late Professor Richard of Paris, as set forth in his *Analyse du Fruit*, translated by Lindley some fifteen years ago. At that time no one had a notion of the true theory of the structure of fruits and seeds, the luminous views of Göthe, although for above twenty years before the public, not being known to a single individual in this country, and all that concerns the seed being still an unexplained mystery.

The embryo called acotyledonous, not being the result of specific fertilization, is not, properly speaking, an embryo at all, and will be adverted to in another place

Chapter XXIV.

Of Abortions, Degenerations, Adhesions, &c.—Of Flowerless Plants.

What has been stated in the preceding pages is to be understood to relate to organs in their usual state; and to be explanatory either of what may be considered normal structure, or, at all events, of deviations which are easily reconcilable with it. This Treatise would, however, be incomplete without some account of the principles upon which it is conceived that all great exceptions to normal structure may be accounted for, and by which they may be reduced to such types as those already spoken of. But as the limits of such a sketch as this forbid the question to be examined in much detail, a few examples only will be given in connexion with very general views.

It must be obvious, from all that has as yet been advanced, that the different parts of which plants consist are extremely simple in their nature; and it is a matter of surprise that such a prodigious diversity, not only of general appearance, but of arrangement and structure, as the vegetable kingdom presents, should result from their combinations. Some French author has indeed said that vegetation is the masquerade dress of nature; it is, however, a masquerade which forms a disguise only to the eyes of those who look at Nature without studying her.

The three principal modes in which the true or typical structure of plants is obscured, are *abortion*, or the non-development of organs; *degeneration*, or their imperfect development; and *adhesion*, or the growth of one to the other.

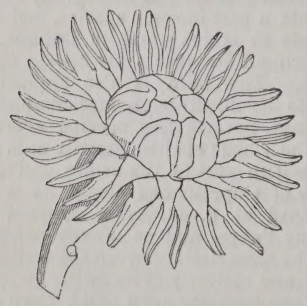
The term abortion would seem to express, that a part shortly after its original creation became deformed and ceased to have the power of further development; such, however, is not the sense in which botanists use it. By abortion they mean the non-appearance of some organ at the place where one would expect that it would appear, and where in fact it would be found if the structure were regular. There are no parts of plants that may not become abortive, either accidentally or normally; for instance, even in branches, it is their abortion in Pine trees which causes the fascicled appearance of the leaves of such plants; if the greater part of their branches were not abortive, the leaves would not be fascicled, but alternate as in common firs. In leaves, very curious instances of abortion take place; it is by that of the leaflets of Acacias that phyllodia are caused to develope (p. 27); and it is the same cause which produces in Stapelia, Euphorbia, Cactus, &c., those remarkable stems (p. 13) which seem to us as leaves. It is this, also, to which we are to ascribe the peculiar appearance of such plants as Chara, Duckweed, and submersed Algæ.

Thus the abortion of the calyx and corolla produces the kind of flowers we find in the Willow, and to that of either the pistil or the stamens is wholly to be ascribed the existence of what are called unisexual flowers. In all plants it is normal that the number of parts in the corolla, or the stamens, or the pistil, should not be less than the multiple of the numbers in the calyx; and all exceptions to this are ascribed to abortion. Thus Lamium, the white Dead nettle, has a calyx with five teeth, a corolla which is reducible to five petals; but only four stamens; in this case one stamen is abortive, as is proved by plants like Pentstemon, in which that becomes developed which is usually undeveloped. A part of the petals in like manner is, in some instances, abortive; as in Cuphea, which wants a part in some species, and the whole in others; and in Daphne, in which all the petals are always abortive. This term is also applied to parts which, although once completely formed, nevertheless become abortive in the course of their growth, as is the case with part of the ovules and carpels of Cupuliferous plants, as is explained at p. 47, as is common in many Palms, and as usually happens in the Rose itself between the fertilization and maturity of its fruit.

Degenerations are a much more fertile source of alteration in appearance; they generally consist in a part being less highly developed than is usual; and may be considered—if viewed in their true light—as explanatory of the true basis of comparative anatomy in the vegetable kingdom (see p. 59). As instances of this, among leaves, may be quoted such plants as Ruellia anisophylla, in which one of the leaves of each pair is minute and unformed; or as Monotropa hypopithys, the bird's-nest Orchis (Neottia), Scalewort (La-

thræa), and many others, all whose leaves are in the degenerate state of scales; the scaly coverings of leaf-buds are also imperfectly formed or degenerate leaves. The calyx is remarkable for the many shapes it assumes when degenerated; in the Elm and the Beech it is nothing but a thin, green, deformed membrane; in the fertile flower of the Fig it is a few unequal bristles; and in many Composite plants it consists of little more than hairs or sharp-pointed scales; and is often so entirely rudimentary as to be nothing but a narrow rim. In like manner the corolla is reduced to a few scales in Buckthorn (Rhamnus), and its interior petals to thread-like processes in the Passion-flower. The stamens again are in part not more developed than as little scales in Scitamineous plants; in Lopezia appear in the form of a spoon-shaped membrane; in multitudes of plants are little awl-shaped processes resembling filaments; and in a curious New Holland genus called Eupomatia, they altogether assume the appearance of petals (*fig.* 76*). Even ovules in a degenerate state are thought to be discoverable in the form of the glands which grow upon the edge of the leaf of a Peach-tree.

Fig. 76*.



But whatever deviations from normal structure may occur in consequence of abortions and degenerations, they are as nothing compared with what is produced by the adhesion or growth of one thing to another, a phenomenon on which depends the very existence of plants as organic beings. Their whole framework is constituted of minute organs in a state of adhesion; their stems may be understood, without doing violence to truth, as combinations of many systems of life; and we see perpetually the existence of this tendency evinced in accidental cases, such as the growth together of two Cucumbers, or of two Apples, or of two or more stems which have been developed in contact with each other. In the hedges, where branches are intertwined very closely, one branch frequently grows to that which is next it, forming a complete natural but accidental union.

This property, which exists thus extensively, is of great and continual operation in veiling the real nature of all the external parts of which plants consist, whether of vegetation or of fructification. Leaves, for instance, grow together by their bases (p. 28, *fig.* 32); the adhesions of stipules cause the production of ochreæ, and that of bracts is the explanation of the cupule or cup of an acorn (p. 33). So are most of the modifications of fructification produced by the agency of the same tendency. The calyx, for example, is normally composed of a certain number of sepals; they grow more or less together, and constitute a toothed cup, a tube, or even an undivided cylinder; the petals also adhere into parts of a similar nature, forming monopetalous corollas; the filaments combine into a sheath for the ovary (*fig.* 51, *f*); the anthers grow into a sheath for the style in Composite plants; the carpels, styles, and stigmas combine to form syncarpous pistils (*fig.* 55); calyx, corolla, filaments, and ovaries, all coalesce into one solid body to form an inferior ovary; and finally, in Orchis, the filaments, anthers, style, and stigma, are consolidated into one columnar mass.

These instances, and a volume might be filled with others such, are abundantly sufficient to show the prevalence of the law, *that all contiguous parts are liable to grow together.*

It must however be remarked, that in all cases of normal adhesion, the growing together seems to take place at a very early period of the formation of the organs; and to be altogether antecedent to their arriving at a perfect state.

Flowerless Plants.—It is probable, although it is not yet susceptible of proof in many cases, that all the curious deviations from typical structure which occur among flowerless plants, are owing to the operation of one or other of the foregoing causes. For example, there can be scarcely a doubt that the repro-

ductive organs of Equisetum are degenerate stamens and pistils; that those which grow on the back of the leaves of Ferns are degenerate leaf-buds; and that the thecæ of Mosses are of a similar nature, although in an extremely different state. So in like manner the scales of Mosses must be considered degenerate leaves; the shining green horizontal expansions of Marchantia adhesions of degenerate leaves to degenerate stems; while the reproductive organs of both Lichens, Fungi, and Algæ are to be reckoned adhesions, abortions, and degenerations of well-known organs, all in one. We do not however propose in this treatise to meddle with this part of the subject, otherwise than in the most incidental manner possible.

Chapter XXV.

Of the Theoretical Structure of Flowers, or Morphology.

Notwithstanding all that has been said concerning the normal or abnormal state of the organs of plants, and the manner in which they are severally combined, there still is wanting some principle of combination by which the relation that they severally bear to each other can be determined, and consequently the existence of abortions or degenerations, which are in all cases interferences with regularity, be detected.

It does not appear that the old botanists, who in fact knew nothing whatever of the theory of structure in regard to the vegetable kingdom, ever suspected that the different organs of plants bore any fixed relation to each other; nor can it be said that Linnæus at all understood this, however near he approached to a discovery of the key of the theory. See *Lindley's Introduction to Botany*, p. 505. It was only after the poet Göthe promulgated the doctrine, that all external organs, of whatever nature, are metamorphosed leaves, that botanists gained a clue by which the mutual relations of plants could be determined, and a flower be proved to be analogous in its structure to a branch covered with leaves. For this grand discovery of necessity led to the conclusion, that if a flower be really a collection of metamorphosed leaves, and consequently a branch, the parts of a flower must of necessity bear the same relation to one another as the leaves of a branch. And this is the true basis of all ideas regarding the parts of fructification of plants. It may indeed appear ridiculous to assert that the fruit of a peach is nothing but a peach-leaf rolled up and thickened, an apple only the leaves in a similar state, and a grain of wheat a single leaf in a state of degeneration; and yet we expect to be able to set this matter before our readers in so clear a light, as to convince them that such an assertion, although startling, would be very nearly true. This is called the doctrine of morphology.

It has been observed, in a report made to the British Association at their meeting at Cambridge in 1833, when adverting to this doctrine, that when those who first seized upon the important but neglected facts out of which the modern theory of morphology has been constructed, asserted that all the appendages of the axis of a plant are metamorphosed leaves, more was certainly stated than the evidence would justify; for we cannot say that an organ is a metamorphosed leaf which, in point of fact, has never been a leaf. What was meant, and that which is supported by the most conclusive evidence, is, that every appendage of the axis, whether leaf, bract, sepal, petal, stamen, or carpel, is originally constructed of the same elements, arranged upon a common plan, and varying in their manner of development, not on account of any original difference in structure, but on account of special and local predisposing causes; of this the leaf is taken as the type because it is the organ which is most usually the result of the development of those elements; is that to which the other organs generally revert when, from any accidental disturbing cause, they do not assume the appearance to which they were originally predisposed; and moreover, is that in which we have the most complete state of organization. It might have been added that the leaf moreover can always be most distinctly traced by insensible gradations of structure into all the other parts. It is this which we now propose to prove; and being proved, it will show the truth o the axiom, that *all the parts of a flower must necessarily be equal to each other in number, and alternate with each other*,, except in cases of abortion, degeneration and adhesion.

The course we shall take is this; we shall prove, 1. The bract to be a modification of a leaf; 2. The sepal to be a modification of a bract; 3. The petal of a sepal; 4. The stamen of a petal; 5. The carpel of a leaf; and 6. The ovule of a leaf-bud; and we shall then have demonstrated the whole of them to be modifications of leaves. It is also to be remarked that if this can be proved of *any* normal plants, it must be true of *all* such; for as their parts are manifestly identical in nature, that which is true of one is necessarily true of all.

It must require but little evidence to convince the most sceptical reader that a *bract* is nothing more than an imperfectly-formed leaf. Examine it in the Lilac; the most gradual transitions may be seen from the one to the other; or examine it in the Pæony, the ivy-leaved Speedwell, and the common briar Rose (Rosa canina). This being established, it follows that all modifications of bracts are also imperfect leaves, and that, therefore, the involucre of an Umbelliferous, or of a Composite, plant, and the cup of an acorn are also aggregations of half-grown leaves. This is step the first.

The transition from a bract to a *sepal* is very easy. In the Strawberry, the calyx is composed of five bracts alternating with the five sepals, and distinguishable from them in nothing but size; in the Pæony, the leaves insensibly pass into bracts, and the bracts into petals; and in the Carolina Allspice (Calycanthus), the same gradual transition is strikingly apparent. Add to this, that in the briar Rose, one of the sepals is always pinnated like the true leaves; that in the Tulip the sepals often become half leaf and half petal; and that in the Apple, Pear, and numerous other plants, a transformation of sepals into leaves is of common occurrence, and the point that sepals also are leaves may be considered established.

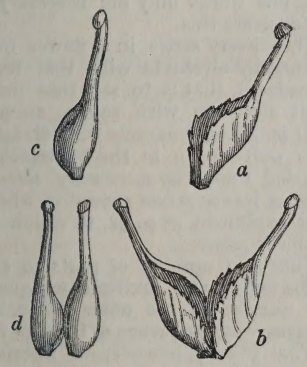
Difference organically between *petal* and sepal there is none, as has already been shown (p. 36); consequently what is true of the one is also true of the other, and petals also are leaves. We may as well, however, add to what has been stated in the place referred to, that petals will occasionally become leaves, or be half changed to them; the latter is common in the Apple and the Pear, it also occurs in some varieties of Rose, and has been seen by Du Petit Thouars in the Tropæolum, by the writer of this in Sieversia montana, and numerous other plants, and may be discovered by any one who will search diligently for it. The petal is, therefore, a modification of a leaf.

A stamen is less obviously like a leaf than any of the preceding parts. And yet if we examine it in the white Water-lily, its relation to a petal, and consequently to a leaf, is incontestable. In the white Water-lily, the innermost petals gradually narrow, and become callous at the point; their edges, also, like the point, become insensibly yellow and dilated; at last a cell full of pollen is formed upon their edges, and a stamen is the result; here it is impossible to distinguish any precise limit between the petal and the stamen, but one is clearly a modification of the other; the same may be said of the Carolina allspice. In double Roses, Pæonies, Tulips, Anemones, Ranunculuses, &c., all manner of transitions from stamens to petals may be detected; and in the Rose œillet of the gardens in particular, it is clear that the filament of a stamen answers to the claw, and the anther to the limb of a petal, consequently the filament is a modification of the petiole, and the anther of the blade of a leaf. The probability of this is further shown by the fact that the two lobes of an anther answer to the two sides of a leaf, and the connective to the midrib; and the fact is proved by accidental productions, such as occur now and then in Umbelliferous plants, where the stamens are replaced by small leaves on long stalks. In special cases of deformation, the stamens become genuine leaves, as in the Sieversia above referred to. The stamen, then, is a modification of a leaf.

That the *carpel* is of the same nature is very easily shown, not only by its constant tendency to revert to the form of a leaf, as is seen in double Roses, Anemones, Ranunculuses, and the like, but more particularly by the double Cherry, in whose flowers Nature has written her laws in a language so simple, and positive, that none but the wilfully blind can misunderstand them. In this plant the centre of the flower is occupied by a small green leaf (*fig. 77, a*) stationed in the place of the carpel, and consisting of two sides folded together, along with a midrib which is longer than the leaf itself, and

slightly dilated at the summit. Upon comparing several of these leaves in different states, with the perfect carpel of a cherry (*fig.* 77, *c*), it is obvious that the two inflected sides of the leaf answer to the ovary, the midrib to the style, and the dilated summit of the midrib to the stigma; and if we compare the internal structure of the ovary with a section of the carpellary leaf of the cherry, it will also be obvious that the inside of the ovary answers to the upper surface of the leaf, the ventral suture to the line formed by the union of its two edges, and that the placenta is merely an expansion of a portion of the margin. In some instances two carpellary leaves occur in a flower of the double cherry, as at *fig.* 77, *b*; and then it is found that

Fig. 77.



they are placed directly opposite each other, the margins being nearly in contact; so also when by any accident the cherry has two real carpels, they also occupy the same position with respect to each other, the ventral sutures, and consequently the placentæ, being contiguous (*fig.* 77, *d*). That the carpel of a Cherry is a leaf, admits then of no further doubt, and consequently a Cherry fruit must also be a leaf, because the fruit is nothing whatever but the mature state of the carpel. Nor, indeed, are the changes that take place in the structure of the Cherry between its young and its full-grown state by any means incompatible with the anatomical structure of a common leaf. The stone of a cherry is the hardened lining of the fruit; it is also the upper stratum of the leaf, which consists, as has been already shown (p. 29), of little bladders placed in a different direction from those of the central and lower strata. The pulpy portion of the cherry will then arise from these latter, distended with fluid and altered in colour; the former phenomenon occurs habitually in the leaves of the House-leek, and of all leafy succulent plants, and the alteration in colour is analogous to what happens to the leaves of the purple Beech, the scarlet Maple, black-fruited Vines, Virginian creepers, and many other well-known plants, in the autumn, when they have reached their full maturity as leaves. That the carpel is a leaf is thus proved to demonstration; and as all compound fruits are collections of carpels, as has already been stated (p. 43), it follows that all fruits, of whatever kind, are modified leaves.

The last step in morphology is to show that ovules, and consequently seeds, are also alterations of leaves. As it appears from what has just been said that ovules grow upon the margins of a carpellary leaf, there will at first sight be a difficulty in reconciling such a function with the well-known fact that leaves do not in general bear anything analogous to ovules. But although it is not a general property of leaves to do this, yet it occurs in a sufficient number of cases to justify the conclusion that it may constantly occur in leaves whose ordinary functions are interfered with by their conversion into carpels. In a common Indian plant called Bryophyllum, the leaves are capable of forming young plants in the crenelling of their border; in the rare little Malaxis paludosa of our marshes, Henslow has shown that bulbs (*i. e.* buds, see p. 13), are constantly formed at the border of the leaves; Ferns often root at the segments of their leaves, in consequence of buds being formed there; so that the production of buds by leaves is not unknown. Now it is to buds, or bulbs, that ovules are to be compared; their integuments are to be considered rudimentary leaves, analogous to the scales of a leaf-bud, and they have actually been seen by Henslow, Engelmann, and others, to change into minute leaves in certain cases of malformation. It is no wonder, then, that bulbs, buds, and seeds (or ripened ovules), should all have a similar power of propagating plants, considering that they are all mere modifications of one common type.

It still remains to be proved that the scales of a leaf-bud, to which we have said that the integuments of an ovule are analogous, are themselves modified leaves. It is true that, if we compare the hard shining resinous scales of the Tacamahac poplar, or the brown woolly scales of the scarlet Horse-chestnut, with the leaves of those trees, we shall be at a loss to discover any resemblance between them; yet by watching them in their growth in the spring, when the leaves are first unfolding, we shall make out their identity in the clearest manner. Take, for instance, the scarlet Horse-chestnut, or the Sycamore. As soon as the buds are unloosened by the movement of the vital principle within them, the outer scales, which are dry and dead, are gradually forced asunder by others, which, although like them in form, still maintain their living powers; of these latter the most exterior lengthen a little, becoming green at their base, but remaining scale-like at their point; those next within them become greener, and have no hardness at the end, otherwise resembling them; the next that are formed produce a little leaf at their points, and themselves contract into a narrower compass, resembling a petiole; finally a greater degree of contraction at the base and of expansion at the point is produced, and a perfect leaf is the result. By this means we are able thus to trace in the clearest manner the identity in nature between the scales of leaf-buds and leaves themselves, and consequently to show that the former are a stunted form of the latter.

Thus by a process of reasoning, and of demonstration, in which no fallacy can be involved, and in which not a single flaw is to be pointed out, we are able to show that all the parts of a flower are modified leaves, analogous to modifications of another nature, which exist in the form of scales of a leaf-bud. Consequently a *flower is a collection of leaves placed in whorls, and therefore is a branch with a short axis*. This explains how it happens that one flower will grow out of another; how monstrous Pears are formed, in which tier upon tier of fruit rise, from a common stalk; for as the parts of a flower are leaves, they must have, like leaves, the power of forming buds in their axils; generally they do not form them, but if they do, the result may either be a common branch growing out of a flower, as in many Roses, or a new flower changing to fruit, as in malformations of the pear.

These principles being established, they are necessarily followed by certain results, which form the basis of the present theory of floral structure; and which may be considered to have conduced more to improve our knowledge of botany than any other circumstance that has occurred in its whole history. These results are:—

1. *That each series of floral envelopes must normally alternate with that which preceded it.*

2. *That the number of parts in every series must be equal to, or a multiple of, the number of parts in the first or outer series.* And

3. *That all exceptions are owing either to multiplication, abortion, or adhesion of parts.*

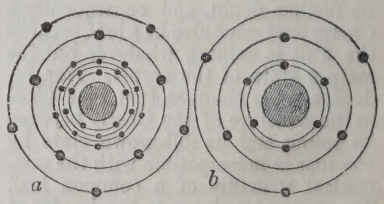
A few words only are necessary to demonstrate this.

That every series in a flower must necessarily alternate with that which precedes it, that is to say, that petals must alternate with sepals, stamens with petals, and carpels with stamens, as is well shown in the houseleek, is founded upon the necessary alternations of leaves when placed in whorls, as is explained at p. 22, to which the reader is referred.

That the number of parts in each series must be the multiple or equal of the number in the outer series, is a necessary consequence of the last rule.

That it may, however, be interfered with by such causes as multiplication, abortion, or adhesion, may be easily conceived, and will be as easily understood by a few examples. First, as to *multiplication*. a Cherry (*fig.* 78, *a*) has a calyx composed of *five* sepals, a corolla of *five* petals, and *twenty* stamens; here four rows of stamens are considered to be present, all, however, blended into one whorl by the closeness of their origin. A Squill (*fig.* 78,

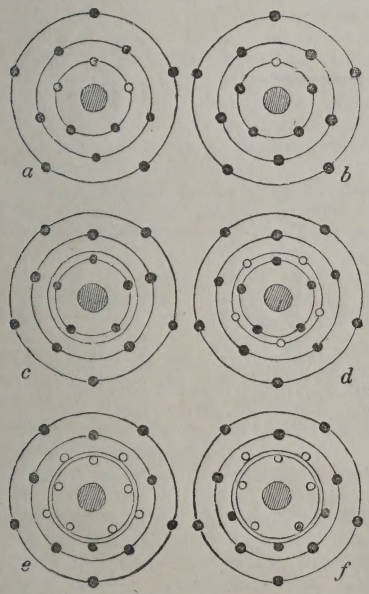
Fig. 78.



b) has *three* sepals, *three* petals, and *six* stamens; that is, two rows of the latter, the first of which alternates with the petals, and the second with the first. This will be at once obvious if, in the above and succeeding diagrams, the outer circle is considered as calyx, the next as corolla, the following as stamens, and the centre of all as pistil; the black dots as indicating the position of organs, which are present in a perfect state, and the white dots those which are abortive.

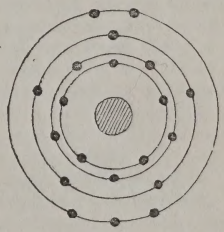
Secondly, as to *abortion:* a Sage flower (Salvia) has a calyx of *five* sepals, a corolla, which, however irregular, is made up of *five* petals, and only *two* stamens (*fig.* 79, *a*); here three stamens are abortive; and upon looking attentively at the inside of the tube of the corolla, two little scales are often to be seen growing alternately with the petals, exactly in the place where the stamens themselves should normally have appeared; two of such scales are very often in other genera, otherwise constructed exactly like the Sage, developed as perfect stamens (*fig.* 79 *b*); and in some others even the fifth makes its appearance, exactly where it should normally be found. In the Primrose the stamens are equal in number to the petals, but opposite them (*fig.* 79, *c*); in this case the first row of stamens is abortive, and the second, which is the only one that developes, is in its true position; while in Samolus, a plant otherwise formed upon the same plan as the Primrose, five scales, which are degenerate stamens, appear in the situation of the first row (*fig.* 79, *d*). In the genus Bauhinia there are species in which, out of ten stamens five only are perfect, or even a smaller number (*fig.* 79, *e f*); the other parts remaining in a normal condition. In the carpels, deviation from the true number, in consequence of abortion or non-development, is so common as not to be worth reciting.

Fig. 79.



It is, however, after all, in adhesions more particularly that apparent deviations from normal structure take place. A papilionaceous flower consists of five petals (p. 38); the calyx should, therefore, consist of five sepals; but in the Lupine, and many others, only two sepals are discoverable. In reality there are five, although they are so combined that their true number is invisible; two uniting into an upper and three into a lower lip of the calyx (*fig.* 80); and in like manner petals adhere till their true number is lost sight of, as in the white Dead-nettle, the calyx of many Labiate plants, and a host of other things.

Fig. 80.



The reader may, however, be assured, that in all such cases the normal proportions are easily discoverable, and that the laws deduced from such morphological considerations as those which have been explained, are fixed and immutable.

In strictness it is in this division of our subject that we ought to treat of the structure of what are called the elementary organs of plants, to which we have already alluded under the name of bladders, air-vessels, &c. But as they may be considered the springs by whose united forces the functions of vegetation are exclusively regulated, and as it is through their agency that the powers of earth, air, and light are brought to bear upon the living system of a plant, and to produce all those curious phænomena of which we shall have to speak almost immediately under Physiology, we believe the plan of this treatise will be best preserved by deferring an explanation of the elementary organs till the appearance of the next part of our undertaking.

Part II.—Physiology.

Chapter I.

Of the Elementary Organs; Cellular Tissue; Woody Tissue; Vascular Tissue.

Although plants are furnished, as has now been seen, with many different organs, by means of which the various actions of their life are performed, yet it would be physically impossible for those organs to adapt themselves to the numerous atmospherical and other conditions to which they are exposed, and to feed, breathe, digest, or grow, deprived as they are of everything like the voluntary powers of animals, if it were not for certain small but highly organized parts, of which they, and all the organs of which they consist, are composed. These parts, the minuteness of which is such as to escape the observation except when aided by powerful microscopes, by adhering to one another in particular directions, now spreading into thin plates, now accumulating in solids of various forms, constitute the stem, and root, the leaves and all that to them appertain, and, consequently, the flowers, fruit, and seed of plants, which thus are to be considered masses of a highly curious mechanism, endued with the vital principle.

Such minute parts, being the organic elements of plants, receive the name of *elementary organs*. They may be described as being closed sacs, formed of an exceedingly thin transparent membrane, and assuming different forms, according to the duties they may have to perform, now thickening at their sides, now lengthening, now forming a spiral thread in their interior, from which they gain elasticity, extensibility, and a certain degree of impermeability.

The mode of illustration adopted in this treatise being by no means favourable to the representation of the appearance of such organs as these, they will be treated of very concisely; especially as the most general notion of their nature is sufficient to enable the botanist to understand their mode of action, provided his notion is accurate as far as it goes; all beyond general statements belongs to Vegetable Anatomy, of which we have no intention to treat in detail.

§ 1.—*Cellular Tissue.*

The most important and the most common of the elementary organs is cellular, or, as the French better call it, vesicular tissue. When cut through, as in the pith of the Elder, it appears something like fine honeycomb, the sides of whose cavities, although resembling a hexagon, are nevertheless exceedingly irregular. If a portion of it is put into water and looked at by transmitted light, it will be found nearly colourless and transparent; and if it be boiled for a short time in water, having a small quantity of potash dissolved in it, it may be easily rubbed between the fingers into exceedingly minute bladders. It was these bladders, or *vesicles*, the sides of which, when cut through, caused the honeycomb-like appearance that was first seen. In their natural state, they adhere firmly to each other; but boiling in a solution of potash destroys their adhesion and sets them free. The pulp of a Strawberry, in like manner, consists of cellular tissue; but instead of being empty, as in the Elder, each little bladder is filled with coloured fluid: in this instance the cells or bladders adhere so loosely that they may be separated by merely rubbing the pulp gently in water. In half-dry fruits, like the Jujube, the mealy matter in the inside of the dried pods of the Tamarind, or the Carob bean, the cells separate spontaneously. Cellular tissue is composed, then, of cellules or little bladders in a state of adhesion; and every partition in a mass of cellular tissue must be double, because it consists of the two united sides of two cellules in contact.

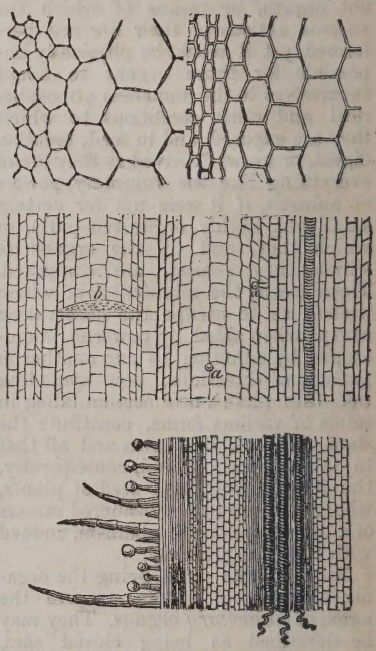
Cellular tissue is most commonly composed of an exceedingly fine transparent membrane; but this latter, in some cases, as on the outside of leaves, or in the bony parts of fruits, becomes so extremely thick, that its very cavity is closed up. In either case, it appears to the eye, even when aided by the most powerful magnifying glasses, to be perfectly homogeneous, without a trace of lines, or holes, or nettings, or of anything of the sort; but, as it has been shown by Lindley to tear with a ragged edge (*Introduction to Botany*, p. 2, t. 1, f. 6), there can be little doubt that its ultimate molecules are arranged in such an order, that they adhere more forcibly in one direction

than in another; and this is rendered the more probable by the tendency which this kind of tissue has to slit and tear in a definite manner when stretched, after being full-grown. An infinite variety of forms, in which this takes place, has been remarked by Purkinje, in the lining of anthers, and elsewhere.—(*See the same work*, p. 10, plate 2).

In size the cellules of cellular tissue vary from the $\frac{1}{1000}$ to $\frac{1}{30}$ of an inch. In some Fungi they are so small, that it has been calculated that a sphere of the size of a large Gourd will contain forty-seven million millions; a number so large that it is difficult for the mind to comprehend it without something to compare it with; it will be more intelligible if it is remembered that if all the cellules of such a gourd are arranged side by side, and two hundred of them covered an inch, which is about their computed size, they would extend rather more than nine hundred miles.

The primitive form of a bladder of cellular tissue is supposed to be the dodecahedron, and it is thought that all other forms are produced by extension or compression. If, for instance, the two poles of such a solid were to be extended, a spindle-shaped bladder, or a prism, or even a cylinder, might be the result; if, on the contrary, its sides were pressed together, it might become a thin disc; and if both extension and compression act simultaneously, other forms might be the result. Thus we find when the cells of plants are formed in a nearly unresisting, or in an equally resisting medium, they assume most nearly the form of some regular spheroid, as in the pith and the pulp of leaves and fruits. When they are generated in parts growing with great rapidity in some particular direction, as in the succulent stems of many herbaceous plants, the stalks of leaves, &c., they assume a prismatical or cylindrical form; and when they are jammed firmly between harder bodies, as in the medullary processes, they become thin plates. This is particularly conspicuous in the medullary processes, the cellular tissue of which is called *muriform*, because, consisting of regular thin parallelograms, it looks as if built up with bricks, as the wall of a house is (*fig.* 89). In some cases, as in the inside of leaves, the cellules look as if lobed, as is represented at page 29, *fig.* 34; this may in some measure arise from the unequal pressure of air upon them at the time of their development; but it is chiefly an optical deception, the lobes being nothing more than cells grown irregularly together.

Fig. 81.

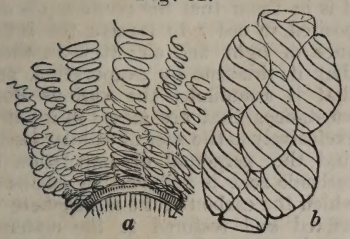


The kinds of cellular tissue which have now been described, however different from one another, are nevertheless very obviously slight modifications of one primitive type; besides these, there are others which are less easily reducible to it. These are *fibro-membranous* and *fibrous*, and what are called *dotted ducts*.

Fibro-membranous (or *reticulated*) *cellular tissue* (*fig.* 82, *b*) is common cellular tissue, with a spiral fibre generated in the inside of each cell or bladder. It has no elasticity, nor anything, as far as we know, to distinguish it, except this circumstance; its most usual situation is in the skin of seeds, in some of the winged kinds of which it is a most beautiful object, as in those of Eccremocarpus scaber; it constitutes the entire plant of the moss Sphag-

num; forms the tubes called *elaters*, by means of which the spores of Jungermannias are dispersed; and is met with occasionally in the inside of the leaves of many plants. The particular use of this tissue is unknown.

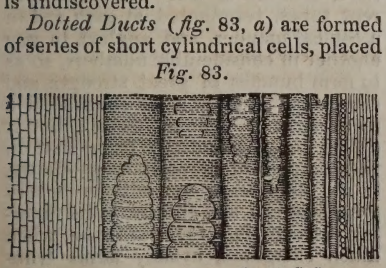
Fig. 82.



Fibrous cellular tissue is more uncommon; it is formed by a fibre either twisted spirally, or arranged irregularly, *without any membrane;* by which circumstance it is immediately known from all other elementary organs. In the lining of the anther it is very common; and it also exists upon the surface of certain seeds, which, when moistened, become covered with mucilage, such as Wild Clary (Salvia Verbenaca) and Collomia linearis (*fig.* 82, *a*). If a seed of this latter be placed under a microscope in water, it will, in a few moments, project from its surface an immense multitude of little spiral threads, which expand in the water and surround the seed like a coating of the most delicate gauze. This appearance is produced by the liberation of the cells of fibrous tissue, which are set loose in consequence of the hard mucilage amongst which they lie being softened, and dart forward into the circumambient fluid, like so many little spiral springs, liberated by the removal of a weight which confined them. Of this kind of tissue the use is undiscovered.

Dotted Ducts (*fig.* 83, *a*) are formed of series of short cylindrical cells, placed

Fig. 83.



end to end, so as to constitute slender columns, extending the whole length of many stems. These cylinders are more or less oblique at their extremities, and are always marked with rows of dots, which appear to be grains of green amylaceous matter; at first, the ends of the cylinders are imperforate, and, consequently, each column is composed of a vast number of closed cavities; but, after a time, the ends of the cylinders are torn open, and the cavities communicate freely with each other, so as to form a tube. At the places where the short cylinders join, oblique lines are seen externally, which are caused by the junction of the cylinders, and being usually more or less oblique, they give the dotted duct something the appearance of a modification of the spiral vessel: hence it has usually been referred to vascular tissue. It is, however, quite certain, from the inquiries of modern observers, that it is, in fact, such a modification of cellular tissue as we have described. Much uncertainty exists as to its real office; it appears, when first formed, to contain air; but after the rupture of the ends of the cylinders it certainly is filled with fluid at the time when the sap is most rapidly in motion; and afterwards it again becomes empty. It is exclusively found in the wood, of which it is one of the parts most early formed. When you look at a transverse section of a piece of Oak or Hazel, or Cane, the little holes which give those woods a porous appearance are the mouths of dotted ducts. They are unknown in Coniferous trees, are unfrequent in herbaceous stems, but may be found with great facility in thin slices of the wood of beach or oak.

Cellular tissue of the common kind, bears the same relation to the vegetable as flesh to the animal frame. It is the basis of every part of which a plant consists; and very often, as in Mosses and the lower tribes of vegetation, it is the only kind of tissue that is formed. In trees, and other woody plants, it constitutes exclusively the pith, the parenchyma of the leaves, the sepals, petals, stamens and carpels, the cuticle, the stigma, and the ovules; in Exogens it forms the medullary processes, and the principal part of the bark; in Endogens it constitutes the whole of the spongy substance in the interior of their stems. It is absent only from the plates of pure woody matter of the stem, and from the veins of leaves, &c., which, in reality, are

an emanation of the woody system. (*See* page 21.)

Cellular tissue is supposed to be capable of performing, by itself, all the more important of the vital actions of vegetation; because there are many plants which live, grow, and propagate themselves, without possessing any other kind of tissue. When combined with other forms it has, however, certain objects in particular, for which it is destined. One of its greatest functions is *to absorb* moisture or gaseous matter, and to part with it again, acting as a sort of living filter. If you place a slice of Elder-pith upon a glass, and allow it to communicate by ever so small a space with water, the whole mass will be speedily saturated; and, on the other hand, it will as speedily part with its water if exposed to a dry atmosphere; not always, however; for in some cases, such as succulent plants, it parts with water very slowly; it, however, does lose it by evaporation through its membranous sides. The latter, then, are eminently hygrometrical, and as they permit mere water to pass through them readily, we must suppose them to be pierced with holes, although the latter are so fine, that the most powerful microscopes that have yet been invented have failed to detect them *.

Having the power of absorption in this high degree, cellular tissue will consequently be well adapted for *transmitting* the fluids of plants from place to place; and accordingly we find it evidently performing this office whereever a very rapid transmission is not required. Being in many cases composed of sacs of a spheroidal shape, it can allow fluids to pass indifferently, in whatever direction a higher-propelling force may exert itself; or when the sacs have an elongated figure, it will then serve to conduct the juices in the direction of the greatest diameter of the sacs. Thus, in pith, there is no particular direction in which the sap is conducted, but it is conveyed by the spheroidal sacs of that part to whatever portion of the contiguous tissue it is required to feed; in the medullary processes, on the contrary, in which the cells are flat parallelograms, with their principal axes directed from the bark to the pith, it is in that direction only that the mural cellular tissue is destined to convey the secretions.

Further, the sacs of cellular tissue being the sole recipients of the sap of plants, properly so called, are the parts in which all the elaboration of the fluid matter of vegetation takes place; it is in them that the crude sap is deposited, in order to receive the influence of light and air; it is in them that it thickens by evaporation, and that it assimilates the various fluid substances that are mixed in it; it is exclusively in the sacs of cellular tissue that the perpetual decomposition of carbonic acid is going on, by means of which the carbon of the atmosphere is refixed and restored to the material substances of the earth; and, finally, it is by the same power of transmission, of which we have already spoken, that the juices, altered and elaborated till they have acquired the properties peculiar to each species, are conveyed from the vegetable stomachs, as leaves may be called, to the bark, stem, and root.

Cellular tissue is moreover the grand agent, by means of which many of what may be termed the mechanical forces of plants are exerted. If, for instance, there are two parts to be torn asunder by contraction, as in the valves of the anther, it is by the shrinking of cellular tissue that it is effected; or if one part is to be burst by the swelling of another, as the Spirting Cucumber, it is to the same kind of tissue that this office is entrusted by nature. In fine, it is the most delicate, the most coarse, the most universal, the most pliable, and the most energetic of all the elementary organs of vegetation.

§ 2.—*Woody Tissue.*

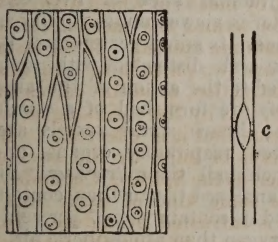
This, which is also called *woody fibre*, consists of thick-sided transparent tubes, terminated at each end in a conical manner, and applied to one another in considerable numbers, so as to form bundles of great strength and elasticity. It is by some considered a mere form of cellular tissue; but it differs most essentially from that in three important circumstances—firstly, in its toughness; secondly, in its very great length; and thirdly, in its tapering extremities. Cellular tissue, when much elongated, usually forms truncated cylinders, as in Cotton, which is a good illustration of it in a lengthened state; when thick-sided it is rarely

* The old opinions concerning the presence of visible pores in the sides of cellular tissue were errors.

tough and elastic; and the longest specimens of tubular cellular tissue are shorter than the shortest specimens of woody fibre. The latter is little subject to variation, except in calibre, in which respect it is found between $\frac{1}{300}$ and $\frac{1}{150}$ of an inch: how slender its tubes usually are may be understood from this, that in hemp, which is a preparation of the woody tissue of the Hemp-plant, it is six times finer than a human hair; each of the filaments into which this substance is mechanically divided before being twisted into thread, consisting of a considerable number of tubes of woody tissue.

It is in Coniferous plants chiefly that the most important of its modifications occurs. In these plants, the sides of the tubes, which are of considerable diameter for this kind of tissue, are marked with large oval glands, which are placed either in single or in double rows, and which appear as if they had a hole or a pimple in their centre (*fig.* 84, *a*). Dr. Mohl, of Munich, has lately

Fig. 84.



endeavoured to show that these glands are shallow depressions or openings from one tube to another, as is represented at *fig.* 84, *c*—the central pimple being in reality a pore; and he represents the appearance of sections of such parts in considerable detail; but as no one has in this country been yet able to detect what this botanist represents, even when assisted by the finest instruments, we must be permitted to doubt whether he has not been misled by imperfect observations; especially as there is no such thing, in fact, as visible pores in any kind of tissue, as far as has yet been detected. What makes *glandular woody-fibre* more remarkable than it otherwise would be, is its exclusive occurrence in Coniferous plants, and genera related to them; on which account it has been found of considerable importance in determining the real nature of many mineralized trunks found imbedded in the early strata of the earth. The reader, who would like to obtain a clear view of it, has nothing more to do than to take a thin shaving of a piece of Pine-wood, such as a carpenter's plane will produce, and to place it in water, beneath a microscope that will magnify about fifty diameters. The great use of woody-fibre is to give strength to every part, and to protect certain of the more delicate organs: it may be considered at once the bones and sinews of vegetation. If it were not for it, the stem of a Willow would be as brittle as that of a Mushroom; but lying as it does across the cellular tissue, it binds it together, and renders all the parts tough by means of its own elasticity and strength. It occurs in the wood, of whose plates or bundles it constitutes the principal part; in the bark, in smaller quantity; in the stalks and veins of leaves, and in the husk of fruits. In the latter positions it forms a sheath to the vascular tissue (*fig.* 86, *c*), rendering the latter at once flexible and protected from injury. It appears highly probable, that in addition to these properties, woody fibre has the office of conveying fluids in certain directions; as, for example, up the stem from the roots, along the veins from the stem, and down the bark from the leaves. It is true that, from the impossibility of actually observing the march of fluids in parts so minute and easily injured as vegetable tissue, no one has been able to demonstrate this; yet one can hardly doubt that such is really its function, when we consider how rapidly the sap flows up the stem of a tree, which consists chiefly of woody fibre; and that, when coloured infusions are compelled to enter the system of a plant, they are uniformly found to pass to the very extremity of the veins, whither it would seem impossible that they should be conveyed, except by means of woody fibre.

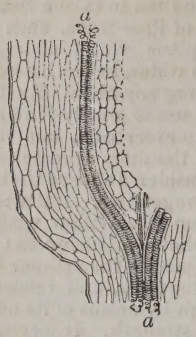
§ 3.—*Vascular Tissue.*

Under this head is comprehended every form of tissue which does not belong to the cellular and the woody. The type of it may be considered the *spiral vessel*, from which the other forms probably are deviations produced by accidental circumstances.

A spiral vessel (*fig.* 85, *a*) is a cylinder, tapering to a cone at each end, composed of exceedingly thin membrane, in

the inside of which one or more fibres are rolled in a spiral manner, so closely

Fig. 85.



that the spires all touch each other. When at rest, it resembles a wire spring, and, like that contrivance, is so elastic, that it will contract, when extended by stretching the two ends.

The toughness of the fibre, of which a spiral vessel is formed, is quite extraordinary, when compared with its excessive fineness. If you pull the stalk of a Strawberry leaf asunder, gently, or the young shoot of a Dogwood, the spiral vessels will be unrolled in great numbers, resembling the threads of a spider's web; by stretching them gradually they may be broken, one after the other, till at last only two or three fibres remain; and they will be found tough enough to bear the weight of a considerable piece of the stem or leaf to which they belong.

Spiral vessels are generally seen by learners in an unrolled state, which is the most easy to obtain, but the worst calculated to give a correct idea of their real nature; for what notion can be formed of the original position of their parts by viewing a parcel of entangled silver threads, glittering in the light, as a mere object of curiosity? One of the best modes of seeing them is to take a piece of Asparagus, in the boiled state in which it is brought to table, and to tear it in pieces in water. By means of a little careful tearing and cleaning, you may extract from the pulp, which is cellular tissue, a quantity of fibrous bundles, which are in part woody fibre, and in part spiral vessels; the elasticity and disposition to unrol, in the latter, being destroyed by the boiling, they may be easily separated in an entire state, when their terminations and the true position of their internal fibre will be distinctly perceived.

Spiral vessels are confined to the veins of leaves, and of those parts which are modifications of leaves, such as sepals, petals, stamens, carpels, and fruit; and to certain places in the stem. In the stems of Exogens, they form the medullary sheath (see page 16 and fig. 13 c), from which they diverge into the leaves, &c. In Endogens they form the central part of every bundle of woody matter, and from these bundles pass into the veins of the leaves, which are mere external elongations of the bundles. They are absent from the bark of all plants (except Nepenthes), and are only found in the root of Endogens. In plants which never bear flowers, they are altogether wanting, except in the form of ducts; the nature of which will be explained presently.

If a stem is cut across under water, air-bubbles form immediately at the mouths of the spiral vessels. If a thin longitudinal slice of live vegetable matter is viewed under similar circumstances, its spiral vessels will be seen dark and distended with air; submitted to the action of the air-pump, proofs are furnished of a similar nature; hence spiral vessels are considered respiratory organs, and the French call them *tracheæ*. Bischoff has analyzed the air they contain, and found it contain 6 or 7 per cent. more of oxygen than atmospheric air. From what source the additional oxygen is obtained is as yet unknown; but it may be conjectured to be produced by the decomposition of carbonic acid in the tissue that lies in the vicinity of the vessels. There are those, indeed, who insist upon the spiral vessels being intended for the conveyance of fluid. But with reference to this opinion, it is sufficient to remark, 1st, that these writers evidently confound ducts and dotted vessels with the spiral, which is a most important error; 2nd, that even if fluids are occasionally found in old spiral vessels, that may only show that they admit water through their sides, when their aëriferous functions are over; 3rd, that the close coils of fibre which line their inside, seem well contrived for hindering the escape of air, and the introduction of water; and, 4th, that there appears to be no provision for the conveyance of air through the central

parts of plants, if that office is not performed by the spiral vessels.

Ducts are organs having a great resemblance to spiral vessels, and are probably a mere modification of them; they are chiefly distinguished by their want of elasticity, and of the power of unrolling. Like the spiral vessels they consist of a very thin cylinder, terminating in conical extremities, and having a fibre twisted, spirally in its inside; but the spires of the fibre are brittle, so that they snap when stretched, instead of unrolling. In the *closed duct* (*fig.* 86, *a*), the fibre is placed exactly as in the spiral vessel; in the *annular* (*fig.* 86, *b*), the spires seem broken into rings, which join at their extremities, and give the organ the appearance of a tube partially filled with rings lying irregularly in the inside; and in the *reticulated* (*fig.* 90 *d*), the spires of fibre touch, and grow together in so irregular a manner as to form a sort of netted bag, with very unequal meshes.

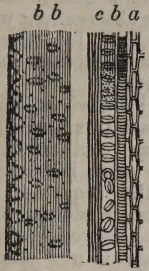


Fig. 86.

The closed duct is found principally in Acrogens, in which it represents the spiral vessel; the others are little known, except in the herbaceous stems of plants which grow with considerable rapidity. They occasionally occur in wood, especially of the Coniferous kind. One of the best plants to examine for the annular and reticulated duct, is the Garden Balsam, or the Touch-me-not (Impatiens), in whose stems they are abundant.

Their office seems to be to convey fluid at one period of their existence, whatever it may originally have been; for they are certainly filled with sap in such plants as those to which we have just referred. Considering their relation in structure to spiral vessels, one cannot avoid suspecting that to convey air was their original destination; but if so, this must have ceased soon after their first creation; for the thinness of their sides, and the very imperfect manner in which they are guarded internally by fibrous spires, are such that no resistance would be offered by them to the infiltration of fluid from the tissue that surrounds them.

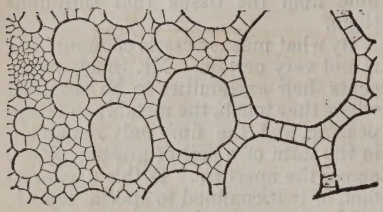
By what means vessels communicate is not very certain. Mr. Slack represents their extremities to be absorbed where they touch, the membrane disappearing, and the fibre only remaining in the form of a sort of grating placed across the aperture. Is this a general fact, or is it confined to special cases?

Many attempts have been made to determine the true functions of these and the other kinds of tissue by causing coloured infusions to ascend them; but the artificial and unnatural circumstances under which such experiments have been performed, the great difficulty of telling whether such minute organs are really coloured by matter that has introduced itself into their cavity, or are only apparently so in consequence of the colouring matter shining through their transparent sides, and more especially the impossibility of ascertaining that fluids do not rise through the *intercellular passages*, have rendered all such attempts so unsatisfactory that they are not worth describing here.

Intercellular passages are the spaces necessarily left between the sides of the vesicles or tubes of tissue when placed in contact. If those vesicles or tubes were regular polygons or prisms, they might be so fitted together that no spaces would be left between them; but being always irregular, and usually spheroids or true cylinders, they are, in fact, analogous to a heap of bladders, or bundles of straws packed together, between the component parts of which considerable spaces must necessarily be left. It is these which, under the name of intercellular passages, are supposed to assist materially in conveying the fluids of plants from one part to another. They are, therefore, not special organs, but only passages between other organs. Of the same nature are what are called *turpentine vessels, receptacles of oil, and air-cells.* The two first are mere cysts; the former fistular, the latter spheroidal, formed in tissue, into which the secretions of a plant are drained; the short irregular tubes in which turpentine lies in the bark of a Fir tree are an ex-

ample of the former: the numerous cavities containing essential oil, in the rind of an orange, of the latter. Air-cells (*fig.* 87) are cavities formed in the

Fig. 87.



leaf or stem, for the purpose of enabling a plant to float in water. They are built up with a degree of regularity which is most admirable: having their sides composed of cellular tissue in different forms, now round, now lengthened, now angular, according to the situation it occupies in the sides or angles of the cavity, and evidently contrived with the most careful foresight: those parts having forms adapted to stretching where any strain is likely to occur, and those being solid and unextensible where there is merely weight to sustain. Than these air-cells there is not one of all the works of the creation more richly deserving the attention of the philosopher, who seeks for illustrations of the design and skill of the divine Artificer of Nature. The leaf-stalk or stem of a floating Crowfoot, or the Duck-weed, obscure and insignificant weeds as they seem, exhibit an elaborate perfection of workmanship, employed merely to render such objects buoyant in water, infinitely beyond the most exquisite architecture of the most gorgeous temple in the universe.

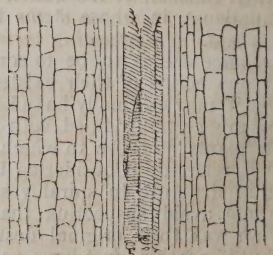
Different as are the various forms of tissue which have been now described, it is the opinion of some distinguished vegetable anatomists that they are all mere modifications of the vesicle or cellule; this is, in particular, the view lately taken of the subject by Mirbel. This distinguished botanist, in a most curious paper on Marchantia, to which allusion has been made on more than one occasion, asserts that he has seen common rounded cells of cellular tissue develope into long slender tubes, tapering into each end; that those, which originally have "membranous, thin, even, transparent, entirely colourless sides, gradually thicken, lose their transparency, and become marked all round, from end to end, with two parallel streaks, which are very close together, and traced in a spiral direction. Afterwards they enlarge, the streaks become slits, which cut the sides of each tube, from one end to the other, into two threads, whose circumvolutions separate, after the manner of the thread of a gun-worm." He also makes some observations upon changes of another kind, by means of which cellular tissue becomes converted into annular ducts.

It must be obvious, however, that observations of this kind, however carefully made and faithfully recorded, are so liable to error, in some of the details, that they require to be repeated by several independent observers before they can be received as positive facts. Even as the case now stands, a different interpretation might be put upon the appearances described by Mirbel himself, admitting them to be described correctly; and as at all events, for all practical purposes, it is indispensable that we should distinguish correctly the three principal kinds of elementary organs which have been here described, it is not desirable to dwell longer upon this part of the subject.

We shall, therefore, conclude the explanation of the structure and functions of tissue with representations of the relative position of the elementary organs in those cases in which their action is the most likely to come frequently under our consideration hereafter. In all the three following figures, *c* signifies cellular tissue, *dd* dotted ducts, *f* woody fibre, *s* spiral vessels, and *d* vascular ducts.

Fig. 88 is a plan of their position in the stalk of a leaf, showing in what

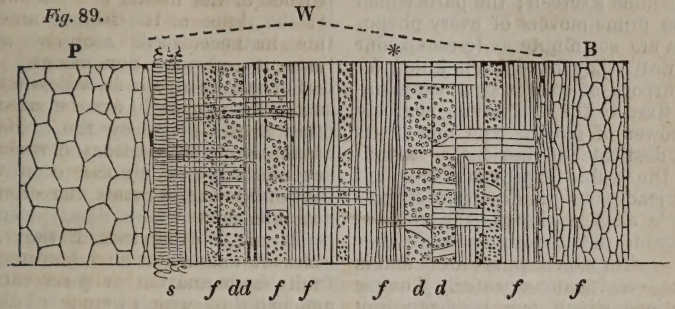
Fig. 88.



order they are respectively placed when the systems of the wood and bark become blended together.

Fig. 89 is a plan of the arrangement of the elementary organs in the branch of an Exogen two years old; P being the pith, W the wood, B the bark, * the limit where the wood or the bark of

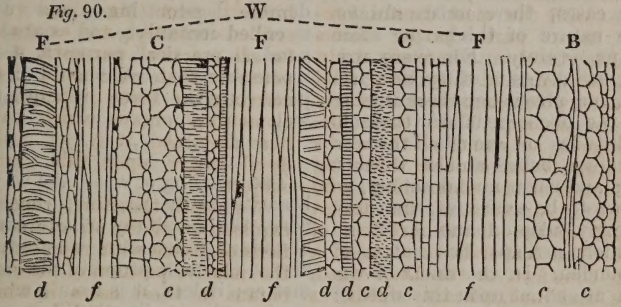
Fig. 89.



one year ceases and of a second begins, and the tissue lying in a horizontal direction across the wood being the muriform cells of the medullary processes.

Fig. 90 is a plan of the arrangement of the tissue in the stem of an Exogen: these details are taken from Von Martius' splendid work upon Palms; B is the cortical integument which answers

Fig. 90.



to the bark of an Exogen; W is the woody centre, consisting of bundles of fibro-vascular tissue marked F, and cellular substance marked C, analogous to the pith and medullary processes of an Exogen.

Chapter II.

General Considerations concerning the Nature of Plants, and the Means they have of performing their vital Actions.

Now that the reader is acquainted with the general nature of all the organs of plants, and that he understands the structure of those minute elementary parts by the united forces of which they are enabled to perform their functions, we may proceed to sketch out the latter in their principal outlines, here and there putting in the shadows, as a painter would say, for the sake of bringing certain objects more distinctly into view, but in all cases avoiding the minuter details; for which the inquirer is referred to works of a more extensive nature than the present.

In this department of the science, the difficulties which the philosopher has to overcome are of a very different character from those which may have embarrassed him in merely determining the organization of a plant. In the latter case good microscopes, manual dexterity in preparing the parts for examination, and sufficient patience for his task, are sure to bring the observer to conclusions, the general truth of which is often susceptible of exact demonstration; but when we come to consider the causes of vital phenomena and the manner in which

they are brought about, we have obstacles of quite another kind to overcome. There is not a function of vegetable life which is not performed, as it were, behind a screen; the parts which are the prime movers of every phenomenon are so minute as to escape our view until they have been killed for the purpose of microscopic examination; fixed to the soil, having scarcely any power of moving any one of its limbs, destitute of passions, or sensations, the visible expressions of which might lead us to the discovery of their invisible causes,—having the whole of its organic mechanism concealed beneath a skin which seems inert and is opaque,—and more especially having no actions which can be, with any exactness, compared to those with which we are necessarily acquainted from their taking place in our own bodies,—we are compelled to trust for all our notions of Vegetable Physiology to induction from data, about which, in many cases, there must always, from the nature of things, be some kind of uncertainty. For these reasons, a great diversity of opinion has existed among physiologists concerning many of the phenomena of vegetable life; multitudes of erroneous theories have obtained belief almost without question; and when an old notion has been shown to be erroneous, the world has willingly adopted another in its place, which, perhaps, has not been less unfounded. In the midst of the confusion attendant upon this state of things, a certain number of seeming truths have been elicited, about which there is daily less dispute; and by taking them as guides, or as tests of the truth of other opinions, the whole subject is assuming a state which becomes daily more satisfactory. What will be principally adverted to in the following pages are the best-known facts and most generally received opinions of the present day. Before, however, we proceed to a systematic consideration of the subject, it will be useful to dwell for a moment upon some of the general properties of vegetable matter, independently of the special attributes of the organs of plants.

§ 1.—*Extensibility.*

One of the most obvious circumstances connected with the growth of plants is the power which the tissue possesses of stretching,—or, in a word, its extensibility. We see a branch increase from a line to half an inch in diameter in the course of a year, and its surface still extending with the expansion of the matter enclosed within it; the tissue of the surface must, in this instance, have acquired many times its original dimensions. The leaf of a Lime-tree is formed as a little scale; in a fortnight after it once unfolds, it will grow, by the extension of its tissue, to a thousand times its original size; a similar occurrence takes place in the petals, the stamens, and all parts where development is rapid. It is true, indeed, that such cases of augmentation arise, in part, from the formation of fresh cellules amongst those which were first created, and that, consequently, an increase in bulk is not owing to extensibility alone; and this is to a great extent the case with bark. Still there can be no reason to doubt that the power of extensibility exists in a very considerable degree. Many cases of what is called irritability, for example, depend, as we shall presently see, upon tissue being stretched up to a certain point beyond which it cannot give way.

§ 2.—*Elasticity.*

The bending of wood, the waving of branches in the air, the springiness of cork, the flexibility of the cane, are abundant evidences of elasticity being also a common property of vegetable matter: indeed, it is from timber possessing this quality that it is so valuable to man.

§ 3.—*Contraction.*

A power of contraction is inseparable from elasticity, which, in fact, depends upon the capability of parts when stretched of resuming their original size with rapidity when the straining power is taken off. Independently, however, of this, it exists in many instances where it could not be suspected by the casual observer. Many cases of what is called irritability are more immediately owing to contraction; as in the stamens of Pellitory (Parietaria officinalis). In that plant the filaments, before the flower expands, are curved inwards and downwards, so that the anthers are inverted at the bottom of the calyx; the face of the filament consists of a lax and soft tissue, which is easily extensible;

their back is composed of a more compact and more rigid tissue; the latter is strained to the utmost in consequence of its forming the convexity of the curve, while the stamens are growing, till the segments of the calyx which keep the stamens down are unloosened: the moment this occurs, and the pressure is taken off, the tissue at the back of the filaments suddenly contracts, and the latter are bent outwards with violence; the anthers opening and scattering their pollen at the same time. Even this latter phenomenon is supposed to be caused by the contraction of the cells that form the case of the anther, which, simultaneously shrinking, exercise upon each other a strain which renders it necessary that something should give way; and as the tissue adheres more feebly at the suture of the anther than at any other part, it is there that the sides of the anther separate, and form an opening for the escape of the pollen. Other instances not less striking of the general power of contraction in tissue deserve to be mentioned. If you divide a stem of any common Spurge (Euphorbia), you will find the milky fluid in which that plant abounds run out of both wounds in whatever direction the pieces may be placed: here it is plain that the tissue is turgid with fluid, which keeps its sides in a state of extension; cutting through the tissue takes off the pressure upon its sides, which accordingly contract and squeeze out the fluid within them. With reference to this phenomenon, De Candolle justly observes, that if the fluid was emitted in consequence of an impulse from below upwards, or from above downwards, it would only run out at one of the two wounded ends; and that if it was discharged merely by virtue of its gravity, it would only flow out when the mouths of the wounded tissue were turned downwards; neither of which cases occurs. In fact, a curious experiment of Van Marum and Humboldt has shown, by something like a demonstration, that it must be contractibility that causes this phenomenon; it is known that animals killed by electricity lose their powers of contraction, and those observers found that Euphorbias, destroyed by that agent, equally lost the power of discharging their milk.

§ 4.—*Hygrometrical Properties.*

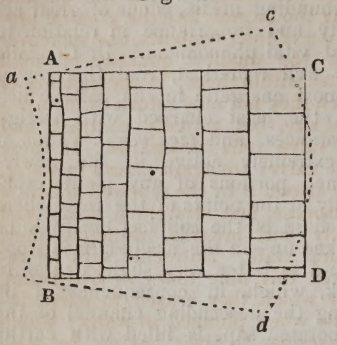
The hygrometrical properties of living vegetable matter,—that is to say, the power of abstracting moisture from surrounding media, is one of great activity and importance in relation to most vital phenomena. De Candolle has well remarked, that this power is most energetic in the parts which are the least charged with foreign substances, and *vice versâ*. Thus it is extremely active in the newly-formed portions of any plant, especially at the points of the root, where the fluid of the soil has chiefly to be sucked up—in the newly-formed wood—and in but a very slight degree in bark, which, in consequence of its being the descending channel of the elaborated sap, is filled with earthy and other matters. Owing, no doubt, to particular organic differences, the hygrometrical powers of particular parts act in very different ways; most capsules burst, and the beards of the Geranium or the Oat curl up, in dry weather; but those of Epilobium and the Fig Marigold (Mesembryanthemum), and most other plants, contract in dry weather, opening only in wet. The latter forms a beautiful object in some of the larger species, which are occasionally brought from the Cape of Good Hope as curiosities. When dry and closed, they resemble an almost-shapeless lump of wood; but placed in warm water they gradually unfold at the point, and by degrees assume the appearance of a star, which, when they are fully expanded, assumes the most perfect symmetry and regularity.

The Rose of Jericho, and the curious Lycopodium of Peru, are other instances of parts unfolding by the application of moisture. These plants are dried up by the burning sun and parching air to which they are periodically exposed, often are detached from the spot on which their slender roots had fixed them, curl up by the contraction of their branches into a round ball, which is blown about by the wind, and becomes the sport of storms. But the moment they are exposed to moisture, their hygrometrical properties cause them to unfold; they suddenly revive, and fix themselves by their own weight to the spot where they receive the influence of moisture.

The cause of the different effects of

moisture upon different plants, in regard to their contracting or expanding, may, perhaps, be understood by reference to the following figure.

Fig. 91.



Let the figure A B C D represent a section of the tissue of any vegetable body. Let the line A B represent the outside, and C D the inside of, we will suppose, the sides of a capsule, which only opens in wet weather, or upon the application of moisture. The cells next the inside C D being larger and thinner sided than those next the outside A B, will absorb moisture with the greatest rapidity and force, and becoming gradually distended will lengthen by degrees; but this will be resisted by the small, thick-sided, and consequently less permeable cells at A B, and the result will be, that as the cells C D lengthen, they will be pulled towards *c d*, while A B will at the same time be forced in the direction *a b* by the general distention of the tissue from C to A, and from D to B; and thus the opening of the capsule will be effected. Reverse the structure, and an opposite effect will be the result; and thus we may understand how it is owing to differences of an organic nature that some parts will unfold and others contract upon the application of moisture externally.

§ 5.—*Endosmose.*

The explanation just offered is that by which Dutrochet accounts for certain cases of what has been incorrectly called irritability. He ascertained by some ingenious experiments, that if liquids of unequal density are separated by animal or vegetable membrane, the thinner fluid will pass through the membrane towards the denser. This may be easily shown by a very simple contrivance: take a common half-ounce phial, the bottom of which has been ground off, and tie a piece of bladder tightly over the opening thus effected. Fill it with mucilage, such as thin gum arabic and water, and half immerse it in water. The denser fluid in the phial will slowly attract the water through the membrane, and the contents of the phial will run over. Reverse the experiment by filling such a phial with water, and plunge the lower end into milk, or sugar and water, or mucilage, and the water will pass out of the phial through the bladder, as will be shown by the water in the phial sinking. This phenomenon Dutrochet called *Endosmose.*

The whole surface of a plant may be considered as a series of bladders, in a state of endosmose—that is to say, as containing fluid of a more dense nature than the aqueous particles that surround them in the atmosphere or in the soil. A plant is, therefore, a sort of endosmometric apparatus, which is incessantly in action, so long as it retains the vital principle, and the force of which is regulated by temperature. This peculiar absorbing power is by no means confined to the surface of a plant; on the contrary, it exists between the internal bladders of cellular tissue and the other elementary organs, wherever there is a difference in the density of the fluid in contiguous cavities; and Dutrochet conceives, with great appearance of truth, that the circulation, as it is called, of the sap, and the distention of one part more than others—or, in other words, the power which some parts have of attracting sap to themselves from the neighbouring tissue, depends essentially upon the phenomenon of endosmose. An instance or two of this will suffice for the present, as we shall return to the subject hereafter. When buds unfold, and grow in the spring, the cells part with some of their water by evaporation; the fluid that remains becomes denser than in those cells which, being more internal, are unable to perspire, and the action of endosmose, which is immediately established, fills the external cells at the expense of the internal ones, which, in their turn, abstract fluid from those which are still more interior. Again, a carpel is fertilized, and is to become a Plum; its cells gradually form in their interior

a fluid of a denser nature than the sap which is near them, and attract it by virtue of endosmose. The circulating system of the plant keeps perpetually supplying the loss thus occasioned, and the plum is thus enabled to become the succulent body which we see. Perhaps the most direct illustration of the effects of endosmose in vegetation may be obtained from the Balsam, a common plant, which any one may procure for experiment. Dutrochet gives an interesting account of his observations upon it, of which the following is a short abstract:—It is well known that the valves of the capsule of the Balsam, when ripe, separate from each other, and that each rolls up spirally, *inwards*—that is to say, that their convexity is outward, or on the side of the cuticle. If you straighten them, they regain their curved state spontaneously and smartly, when they are left to themselves. If they are thrown into water, they curve with greater force than ever; but if they are allowed to become half dry, they fall into a flaccid state, and lose their elasticity, which is however restored by placing them again in water. This shows that the presence of water in the tissue of the valves is at least one of the causes of their rolling up. Upon examining the tissue of a valve, it will be found composed of little bladders, the largest of which are next the cuticle, and the smallest next the inside, gradually diminishing in size from without inwards (or being as represented at *fig.* 91, taking C D for the outside). Considering what the effects of endosmose are in other cases, it may be conceived that the violent incurvation of the valves of the Balsam may be owing to this phenomenon acting principally upon the external vesicles, distending them with fluid attracted from the rising sap, and giving them, when thus distended, a curve outwards, in consequence of the resistance of the base and apex of the capsule; and that, whenever the valves become so turgid as to burst from the extremities of the capsule, which keep them in their place, they will immediately lengthen and curve inwards. To ascertain how far this may be true, take a little syrup and water, which shall be denser than the fluid in the cells of the Balsam-valves; place the latter in it, and they will first straighten, then curve backwards, and at last roll up in the opposite direction from that which is natural to them. This arises from the syrup abstracting the thinner fluid from the bladders of the tissue of the valve, when the valve rolls backward, because the bladders next the outside, being the largest, lose the greatest proportion of their contents, and moreover have the smallest quantity of solid matter within them; in consequence of which they not only return to their original size, but actually contract, and the valve rolls backwards. If these same valves are again placed in water, they attract it by the renewed action of endosmose, first straighten again, and finally curl inwards, resuming their natural state. Dutrochet says he repeated this nine times in five hours, after which they ceased to curve inwards when plunged in water; which he ascribes to their having, by such frequent exposure to the action of the syrup, been gradually robbed of their dense contents. But when placed in syrup, they still continued to roll backwards with an increased energy, because the fluid they still contained had gradually become less dense by the repeated dilutions with water which it had experienced. If a thin slice of the valve of a Balsam be placed under a microscope, the whole of this mechanism may be distinctly beheld. The cells will be seen to diminish rapidly in diameter, especially the larger ones, in consequence of their being emptied, and the valve will gradually reverse the direction of its curve.

Endosmose must be considered, then, as a phenomenon, to the effects of which the greatest importance is to be attached. This will be shown more completely hereafter.

§ 6. *Irritability.*

The various powers of which an explanation has thus been given, however important they may be, do not of themselves account for any one of the phenomena of vegetation. All of them may and, indeed, do, exist in dead matter; the living principle is still wanting to set them in action, to regulate their reciprocal efforts, and to modify them according to the special constitution of different plants.

It would be a waste of time to speculate upon what this living principle may be; and we should have no ambition to invade the province of the psychologist, unless we thought ourselves

likely to discover something more than the subtleties of metaphysicians have yet elucidated. It is sufficient for the world to know—what, indeed, is all that it can know—that the principle of life is a something which is dispersed through all organic matter, and which not only sets the organic elements in action, but preserves them from entering into that state which quickly leads to their return to inorganic substances.

It is under the names of *irritability*, *excitability*, and *sensibility*, that the more immediate effects of the vital principle have been discussed by physiologists. For all practical purposes these may be considered as the same; for even sensibility, by which is meant something analogous to sensation in animals, is not, in vegetable physiology, distinguishable from the two others.

There are those, indeed, who have endeavoured to show that sensation, properly so called, exists in plants; and they have founded their opinions upon certain curious phenomena. The singular power of motion, when touched, for which the Sensitive-plant is so celebrated, has been supposed to be an extreme instance of this; and Dutrochet has even attempted to show that the nervous particles, in which sensation specially resides, are visible to the eye. Great numbers of little green balls of amylaceous or resinous matter are discoverable by the microscope sticking to the tissue of most plants. In the Sensitive, at a little swelling at the base of the leaf-stalk, in which the greatest degree of motion resides, they are particularly abundant; and what is extremely curious, these balls, or granules, are found to be affected by certain chemical agents in the same way as the nervous particles, or what are so considered, of certain molluscs. Boiled for a short time in nitric acid, they become opaque, and regain their transparency upon being plunged in a solution of caustic potash;—but the same granules exist in an equal degree in plants which have nothing approaching to sensation; so that their function cannot be admitted to have anything to do with it. Secondly, poisons have been found by Macaire and Marcet of Geneva to act in the same way upon plants as upon animals; corrosive poisons stiffening the organs as if they produced a sort of vegetable inflammation; narcotic poisons relaxing the whole system, and causing something that has been considered analagous to stupefaction. Hence it has been concluded, that there must be something analogous to *the scattered elements of a nervous system* in plants. Brachet, a French physiologist, has even gone further, and has very recently endeavoured to prove that the pith is the seat of the nervous system in plants, and that the medullary rays are nervous branches. The statements of this writer do not deserve serious refutation; and with regard to the effects of poisons, I do not know that it is necessary to go so far as to admit the presence of a nervous system, in order to account for their effects, especially where there is so much reason to object to the opinion. Upon this subject we cannot do better than quote the words of De Candolle, the celebrated Professor at Geneva:—

"The nervous system, which is very evident and distinct from all others in animals of the upper classes, gradually tends to divide; and finally one is forced to admit, that in zoophytes the nervous matter is diffused, as it were, throughout the whole body; so that the latter possess a kind of universal sensibility, without there being any where a nervous system distinct from the tissue. Hence, say they, we arrive at the vegetable kingdom, where the nervous system is incorporated with the whole tissue; but if this conclusion is to have any probability, it must be shown that the plants which have the greatest resemblance to zoophytes in structure are also those in which the symptoms of sensation are the most evident; which is not the case. All the plants in which it has been thought that it might be perceived, are at the other end of the scale of organization; and consequently the analogy deduced from the animal kingdom does not lead, with anything like force, to the admission of sensation in the vegetable kingdom. Let it also be remarked, that all the most constant and most common phenomena of vegetable life seem to be intimately connected with, and even are necessary consequences of, the absence of spontaneous motion. But spontaneous motion, wherever it exists, is evidently the result of sensation; whence one has a right to conclude, that where the former is wanting, the latter is wanting also."

It is to irritability that we are disposed to refer all the powers which the

organs of plants possess of performing their functions. We know that, in the absence of all stimulants, they are incapable of action. Under this name we would include, in particular, light, heat, and moisture; for all these being abstracted, plants are incapable of maintaining their existence. It is not often, however, that the effects of these agents are manifested by visible signs; it is only in cases where irritability is in excess that we perceive them. The leaves and flowers of all plants are excited by the stimulus of light; but it is only when the petals close or unfold, and that leaves droop or raise themselves erect, that this phenomenon strikes us—that is, when the irritability is excessive.

We feel the more justified in considering what are called cases of vegetable irritability to be merely the vital principle in a state of concentrated action, from this circumstance—that no one has yet been able to throw the smallest light upon the cause of the motions of plants, or to give us anything beyond an explanation of the mechanical means by which the vital principle is enabled to take effect; for we feel quite justified in asserting, that Dutrochet, after all his patient investigations and ingenious experiments, has not advanced one step beyond this.

For the sake, however, of those who may be interested in pursuing such an inquiry, we will mention a few cases which may be easily witnessed of vegetable irritability in excess.

If you touch the surface of the branches of a Lettuce plant in flower, milk will be immediately emitted by the cuticle at the place where it is touched. Here it is supposed that the cellular tissue below the cuticle is in a high state of irritability, and by its contraction forces the milk out through the stomates.

If you touch the filaments of a Kalmia or a Barberry with the point of a pin, near their base, in the inside, they will curve forward, and strike their anthers against the stigma.

The Monkey-flower (Mimulus) has a stigma with two broad thin lips, which stand apart in fine warm weather. Touch them at that time with a bristle, or any such thing, and they collapse suddenly with considerable force.

A plant found in Carolina, called Venus' Fly-trap (Dionæa), has long bristles proceeding from the edge of its leaves, and curving inwards like the teeth of a rat-trap. Touch the surface of the upper side of the leaf, the sides will collapse, and the teeth will close up with such force that it is difficult to separate them again.

A very common plant in the greenhouses of curious persons in the Stylidium, many species of which inhabit New Holland; it has a long column, composed of stamens and style united, springing from the centre of its flower: when at rest this column bends down over one side of the corolla, as if it wished to conceal itself; touch it, however, ever so lightly, and it starts up with a jerk, and rapidly swings over to the opposite side of the flower.

The Sensitive plant has its leaves divided into a great number of leaflets, which spread flat in the sunshine, and seem as quiet as other leaves; but only touch one of the leaflets, and the whole system of the leaf will be irritated; all the leaflets will rapidly collapse, one after the other, till at last the impulse is communicated to the base of the leaf-stalk, which immediately curves downwards. After a time it rises again, the leaflets unfold, and the leaf resumes its original appearance and direction.

§ 7.—*External Agents.*

Light, heat, and water are the external agents which, acting upon the vital principle, set all the machinery of vegetation in motion. No one of these causes will by itself produce any effect, although their combined action is of the most powerful kind.

Light, as we shall hereafter see, causes the decomposition of carbonic acid, fixing the carbon in the interior of tissue, and thus solidifying the most delicate parts, or altering the chemical nature of others; it is the grand cause of the varied colours of vegetation, and may be considered as being in part what produces a motion of the fluids. In its absence plants are weak and sickly, and soon perish.

Heat, by drying the atmosphere, produces evaporation, which is one of the great means by which the crude fluids become inspissated and altered in their nature; it causes the expansion of the gases which plants contain, distends their tissue, and renders the latter more capable of performing its

contractile and hygrometrical functions.

Water relaxes all the parts, dissolves the soluble matters which are laid up in a plant in a state of torpidity, and softens the tissue till it is capable of receiving the influence of temperature. It is, moreover, the medium by which the nutritious principles that are deposited in the earth are absorbed by the roots, and conveyed from one part of the system to another.

To sum up, in few words, all that has thus far been stated, it is light, heat, and water, acting in concert upon an irritable membrane, which enable plants, by virtue of their extensibility, elasticity, and hygrometrical powers, to perform the phenomena of contrac tion and endosmose, by means of which they absorb and digest their food, circulate their fluids, develope their organs, increase in size, and reproduce themselves.

What are the more immediate causes of the principal vital phenomena will be explained, as far as we at present understand them, in succeeding chapters.

CHAPTER III.

Of the Food of Plants.

There are those who have insisted that pure water is the food of plants; others have believed that plants have the power of selecting their food from among the various soluble matters surrounding their roots; and others, again, have declared that the air is alone sufficient to maintain a plant in health. These opinions, founded upon imperfect or ill-conducted experiments, are none of them exactly correct; although they each have a certain quantity of truth. The fact seems to be, that what may be called more particularly the food of plants, because it is that without which they cannot exist, is atmospheric air and water, in which carbonic acid is dissolved; that this alone is sufficient for their support; but that, under natural circumstances, they receive into their system a great variety of other substances dissolved in water; apparently not possessing any power of refusing to absorb whatever soluble matter may be offered to them, whether it be nutritious or deleterious.

We shall not occupy our pages with a description of the proofs by means of which modern chemists have shown the fallacy of the old experiments to prove that pure water is the food of plants; nor is it worth entering into a discussion of the causes of the errors of another nature which have led to the adoption of the opinions that plants can *select* their food from the soil. All that we can pretend to do, is to show upon what evidence the doctrines we state to be now received are based.

It is well known that pure water, as it is furnished by distillation, does not exist in nature; but that it is constantly mixed with earthy, saline, and gaseous matters, which vary in proportion according to the circumstances under which the water is impregnated with them; such water as this is necessarily what is offered to plants as their food. From the decomposition of the various organic substances which are buried in the soil results a considerable formation of carbonic acid,—a principle readily soluble in water, and consequently forming a considerable part of all the fluid introduced into the roots of a plant. The saline and earthy matters which find their way into the system are gradually deposited, almost unchanged, in those parts where the water in which they are dissolved evaporates; namely, in the leaves or the bark, or in some other part of the surface. But the atmospheric air, water, and carbonic acid become decomposed, and their elements, recombining in new proportions, form the materials for new parts, and the gum, fecula, sugar, azotic products, and other immediate principles of the vegetable kingdom.

If the roots of a plant are placed in a close vessel, in distilled water, from which carbonic acid has been carefully expelled, the plant may increase a little in size, in consequence of the decomposition of the water and the combination of its elements with the vegetable system; but it is only when carbonic acid is added that the plant acquires its natural vigour and rate of growth.

It is only in the state of carbonic acid that carbon can enter into the system of a plant; the former is easily decomposed, the oxygen is liberated, and the carbon remains fixed. But if a plant is placed in solid carbon, and you water it with distilled water, it might as well be planted in powdered glass, until the carbon begins to com-

bine with the oxygen of the air, and to form carbonic acid. Sir Humphry Davy placed a plant of Mint in water mixed with carbon, in a state of impalpable powder, and he found that not a particle could enter the roots. If we look to the effects of manures, we shall find that in most cases, except when their object is to alter the state of the soil mechanically, or to act as stimulants, as is probably the case with sulphate of iron, their energy is in proportion to their capability of forming carbonic acid. Yeast, for instance, which is one of the most active manures we have, is so from possessing, beyond all other substances, the power of exciting fermentation, and thus of causing the formation of carbonic acid among the vegetable matter which lies buried in the soil.

While, however, all experiments combine to prove that carbonic acid is the most essential of the elements upon which plants are nourished, it is necessary that the student should be aware that other species of matter are constantly taken into the system, and probably, therefore contribute to their nutrition.

Water is one of these. Although we know that a very large proportion of all the water absorbed by a plant is lost again by evaporation, yet the experiments of Theodore de Saussure have shown that a portion of it is actually solidified. He found that when plants are grown in a close vessel, in an artificial atmosphere, containing a little carbonic acid, the weight which the plant acquired in a given time was augmented, not only by the quantity of carbon produced by the decomposition of carbonic acid, but to a much more considerable extent, which could only be ascribed to its having fixed a considerable quantity of water; thus plants of Vinca, which, in a vessel without carbonic acid, had gained $1\frac{3}{4}$ grain from water, acquired $5\frac{5}{10}$, when they were at the same time able to procure carbon. The same excellent observer has computed, that if we calculate with the utmost care all the weight which a plant can gain either by fixing carbon, or by depositing earthy, saline, alkaline, and metallic matter which they borrow from the soil, or by respiring oxygen, or from the soluble matter of soil, we shall not be able to account for more than a twentieth part of the real weight of such a plant. The other nineteen-twentieths must, therefore, be fixed water. Whatever errors there may be in calculations of this nature, there cannot be a doubt that they are correct to so considerable an extent as to oblige us to admit that water forms a considerable part of the solid tissue of plants; so that it would appear that, like minerals, plants have a water of crystallization independently of their water of vegetation.

As it has been pretty well made out that all the oxygen given off by plants is produced by the decomposition of carbonic acid, and as no one has ever been able to detect the emission of hydrogen by any plants except Mushrooms, it is inferred that, if the water which is consumed by plants is ever decomposed, it is in the formation of the various secretions which contain more oxygen (acids), or more hydrogen (oils), than water; but as the greater part of vegetable substances, such as gum, sugar, fecula, &c., contain oxygen and hydrogen in the same proportions as water, it can hardly be doubted that the greater part is undecomposed and simply fixed.

It was formerly thought that nitrogen, or azote, has nothing to do with the nutrition of plants, and that in those cases where it was met with it was merely in a state of separation from the atmospheric air which had been inhaled and deprived of its oxygen and carbonic acid. But its constant presence in combination with the tissue of Mushrooms and of Cruciferous plants, in gluten, and what chemists call vegetable albumen, and also in vegetable alkalies, seems a sufficiently strong proof of its contributing, in some way or other, to the nutrition of the vegetable system.

We might stop here in explaining the nature of the food of plants, if it were not for the great quantity of metallic, earthy, and other matters which are taken up by them from the soil, and afterwards deposited in their tissue; matters which possibly do not contribute to their nutrition, but about the real nature of whose action we have no evidence.

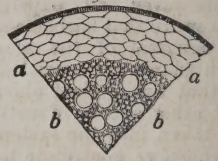
One of the most remarkable of these is silex, which is secreted by certain plants in prodigious quantity. All Grasses abound in it; usually it fixes itself in their cuticle; but in the Bamboo it is also deposited in considerable

quantity in their hollow joints under the form of the substance called Tabasheer. The skin of the Rattan Palm abounds so much in silex that it will strike fire with a piece of steel; the same substance exists in Teak and other kinds of wood, to which it gives a peculiarly gritty texture; and in the genus Equisetum, or Horsetail, one species of which is used for polishing wood, in consequence of the whole surface being composed of compact silicious particles. It was once thought that silex must be actually formed by the action of the vital principle of vegetation; but Berzelius has proved that newly-forming silex is soluble in water, and consequently it is more probable, as has, indeed, been recently proved, that it is in a state of solution that it enters the system, and is afterwards separated from the water. Considering the immense quantity of water that passes through a plant in the course of its growth, there is no difficulty in conceiving the possibility of the largest amount of silex which is ever met with in vegetation originating in this way; but there is still one circumstance to be accounted for. If we grow a Pea and a grain of Wheat in the same soil, the plant which results from the latter will abound in silex, while that from the former will not. Now we have no reason to suppose that these two species have any special power of selecting their food, and that the silex passes freely into the one while it is stopped by filtration in the other case: on the contrary, all that we know of the functions of roots leads us to believe that both absorb the silex equally. What then becomes of it in the Pea? This is a question still to answer.

Lime, and many of its salts, especially the sulphate and phosphate, magnesia, potash, soda, sulphur, phosphorus, several metals, and a number of other species of matter, occur in plants, in greater or less abundance, all evidently taken up from the soil. Of these soda is the best known and most abundant, existing to the amount of as much as fifty-five per cent. in the state of a carbonate in the ashes of Salsola sativa in Sicily (*Fée*); and copper the least suspected and most curious. This metal is stated by Sarzeau, according to De Candolle, to form eight parts in a million in coffee, and about four parts and a half in a million in wheat; whence this chemist has calculated that we annually import into Europe more than 1200lbs. weight of copper in our coffee, and that the French annually consume nearly 8000lbs. in their bread.—(*Journal de Pharmacie*, 1830, p. 505.)

By what means plants are enabled to procure the various kinds of matter which we have seen to enter into their system, is the next subject of consideration. The roots are no doubt the organs which are specially destined for this office; it is they which are placed in the most favourable situation for such a purpose; and which, from their organization and mode of growth, seem also to be the best adapted to it. When young they consist of a sheath of thin and exceedingly hygrometrical cellular tissue (*fig.* 92, *a a*), surrounding a

Fig. 92.



bundle of woody and vascular matter, *b b*. At this period they contain mucilaginous matter, which enables them to attract fluids from the soil that surrounds them, and having obtained it, they send it upwards into the general system. The power of suction which is thus given to them is incessantly in action, and with a force that is almost incredible, considering the smallness of the means by which it is effected this will be evident when it is seen with what force the sap of a plant is impelled upwards at certain periods of the year (*see* Chapter VI.), and when it is mentioned that Hales found a Sunflower, three feet high, lose twenty ounces of water daily, to supply which the roots must have obtained from the soil not twenty, but thirty ounces of fluid daily; for, according to Senebier, a plant retains, on the average, one-third part of all the water that enters its system, and fixes it in a solid form.

It is only, however, in their youngest state that the roots have this extraordinary power; as soon as their tissue becomes charged with earthy matter, deposited by the entering fluids in their passage from the soil, their power of suction is diminished, and seems in the end to cease altogether. Thus, if you take a carrot and place the point

of its root in water, it will suck up the moisture as well as if the whole root were immersed; and on the other hand, if you place the whole root in water, except the point or newly-formed part, it will not suck up the fluid in any considerable quantity. For this reason the young tips of the roots are of the utmost importance to a plant, and its well-being depends in a greater degree upon their preservation than upon any other circumstance. In consequence of the great importance of the tips of the roots, they have received the special name of *spongioles* or *spongelets*, and are sometimes spoken of as if they were really distinct organs; they are, however, nothing more than the young and tender extremities of the roots. As fast as they solidify, they lose their power, and cease to be spongelets; but as the roots, when growing, are incessantly forming new matter at their points, spongelets are perpetually present, notwithstanding that they are perpetually disappearing.

If we take this circumstance in connexion with the fact, that, in general, *roots* do not *lengthen* except by the addition of new matter to their points, we shall find that the function of feeding in plants is one of the most beautiful instances of contrivance in the whole vegetable kingdom. Growing, as they do, in a solid resisting medium, if they lengthened by a general extension of previously formed parts, they would be constantly interfered with by the uncertain nature of the earth in which they are developed; as the degree of resistance offered by soil to any solid passing through it, is, from its very nature, most unequal and uncertain, it would be impossible that the force with which the roots push forward could be ever proportioned to the resistance opposed to their advance, and, consequently, they would become so twisted and knotted, that their fluids would no longer circulate through them with the regularity required by the exigencies of the stem and leaves. And if they absorbed fluid from every part of their surface, the soil round a tree must become so dried up, that, as the roots cannot stir from the place where they are first formed, they would speedily perish from the consequences of their own action upon the earth that surrounds them. Providence has, however, so contrived them, that they are exposed to no such effects. Increasing by constant additions of young matter to their delicate points, they are able to insinuate themselves between the solid particles of the soil with the greatest facility, in which they are much assisted by the softness and pliability of their newborn tissue; thus we find them able to pierce the little cracks in a stone till they have passed beyond it, when their power of expansion will often enable them to burst it; and we often see them insinuating themselves into the crevices of walls, and penetrating solid masses of brickwork. If, however, the rootlets insinuate themselves into a crevice to which there is no outlet, they are merely arrested in their advance; and the facility with which they subdivide into other branches, enables them immediately to counteract the inconvenience produced by their stoppage, by emitting from their sides a number of little sprouts, each of which will advance into the soil in search of moisture. The same property prevents their exhausting the soil of the moisture that surrounds them, for they are all their lives long removing from the exhausted point to new and untouched soil; and this so effectually, that animals, with their powers of movement to aid them, are not better able to roam in search of fresh pastures, than the seemingly motionless roots are to seek incessantly for new feeding places. Some plants will send out their roots, under particular circumstances, to great distances in search of food; and their length will be amazingly disproportionate to the height of their stems. The Lucerne plant has a stem about two feet high; its roots have been taken from below the face of the escarpment of a sand-pit, as much as thirty feet in length; so that many of the little leaves had to be supplied by a living well three hundred and sixty times deeper than themselves. Powerful and important as the action of the roots must be, we must not suppose, on that account, that it is the sole medium by which nutritive matter passes into the system of a plant. Orchideous plants, and certain species of the Fig, have been suspended in the air, and they have continued to live, although their roots were destroyed; a species of Tillandsia is tied to the iron balconies of the houses in Buenos Ayres, and there it

lives and flowers; the Dodder clings round the stems of the Heath and Furze, and grows, flowers, and fruits during the greater part of its life without any communication with the soil; Misletoe has been made to sprout upon the surface of a cannon-ball; and other instances might be mentioned in which plants have grown without roots. If plants which have withered are syringed, they recover their freshness; and if the atmosphere of a badly managed greenhouse is saturated with moisture, the starved and dying plants recover. In all these cases it seems impossible to doubt that a certain quantity of moisture, and consequently of food, is absorbed by the surface of a plant, independently of roots; for we cannot ascribe all the cases just referred to, to the prevention of evaporation. Nor, indeed, does one see why we should; for any soft and succulent tissue is, as we have seen, capable of absorbing moisture through its sides in a greater or less degree, and such tissue exists on the bark and leaves of all plants. It must, however, be remembered, that whatever power we may ascribe to the leaves and stems of plants of keeping up the nutrition of the system in the absence of roots, yet that their power is as nothing compared with the efficiency of the roots themselves.

If, then, it is by the roots that plants are enabled to feed, and if it is more especially by their young and tender points, the importance of preserving those delicate organs must be obvious, while the mischief that will of necessity result from their mutilation or destruction will be readily appreciated; for although they may be renewed when destroyed, yet their replacement is a slow operation, and, in many species, is performed with difficulty, except under very favourable circumstances. The reader who is acquainted with gardening or planting will not fail to perceive the immense importance of these considerations as connected with transplanting trees; and that the violence and carelessness with which plants are frequently torn out of one place and thrust into another, are anything but calculated to ensure a successful result.

Chapter IV.

Of Digestion; or the means by which the crude Sap is converted into the peculiar secretions of Plants.

When the food of a plant enters the roots it passes upwards, undergoing some kind of chemical change, and dissolving whatever soluble matters it meets with in its course; so that, without having been exposed to any of those conditions by which it is ultimately and principally affected, it is considerably altered from its original nature before it reaches the leaves. If the trunk of a Birch tree be tapped in the spring, near the ground, it will discharge in great abundance a whitish limpid fluid, which is the rising sap; but if the sap be obtained from an aperture five or six feet higher, it will be perceptibly astringent; and at a higher point still, its difference from that near the root will be still more apparent.

It has already been remarked, that a portion of the water which plants suck up, combines with the tissue, and enters into the general constitution, where it becomes fixed, as the water of crystallization in minerals. This apparently takes place in the course of the ascent of the sap, before the latter reaches the leaves and becomes exposed to that sort of decomposition and alteration which is here called digestion, and with the phenomena attendant upon which we are best acquainted. Under what influences, except that of the vital principle, a decomposition of the sap takes place before it reaches the leaves, we are ignorant. But when it has reached the leaves, and thus becomes exposed to the effect of light, its action is less removed from our powers of observation; and physiologists have succeeded in ascertaining, to a great extent, the exact nature of the changes it undergoes.

What we find it most necessary to insist upon in this place, are the three following axioms, to which the experiments of careful observers and skilful reasoners have led:—1. *The quantity of water lost to a plant by evaporation, and its power of absorption from the soil, is in proportion to the quantity of light.* 2. *Light causes a decomposition of the carbonic acid of vegetation, and consequently, by solidifying the tissue, renders the parts most*

exposed to it the hardest. 3. *The digestion of plants chiefly consists in a loss of water by evaporation, and in an acquisition of carbon, by the decomposition of carbonic acid.*

That the quantity of water lost to a plant by evaporation is in proportion to the quantity of light is easily proved by the following experiment, mentioned by De Candolle:—"If you select three plants in leaf, of the same species, of the same size, and of the same strength, and place them in close vessels, one in total darkness, the other in the diffused light of day, and the third in the sunshine, it will be found that the first pumps up very little water, the second much more, and the third a great deal more than either. These results vary according to species and circumstances; but it uniformly happens that plants in the sun absorb more than those in diffused light, and the latter more than those in darkness; the last, however, pumping up something. If, again, we take three similar plants, and, preventing their absorption by the roots, after weighing them carefully, place them in three similar situations, we shall find that that exposed to the sun has lost a great quantity of water, that in common daylight a less amount, and that which was in total darkness almost nothing." Hence it may seem proved, that the action of solar light is the great exciting cause of suction at the one end, and of evaporation at the other end of a plant; and that, in the night-time, plants gain weight, while they lose it in the day-time. It is not, however, clear, that, to speak rigorously, although we may talk of light as being the sole cause of these phenomena, it is not rather the dryness of the atmosphere, caused by the heat of sunlight, as compared with the moisture of the air in the absence of the sun. Thus, plants in a dry sitting-room, to which the sun has no access, undoubtedly perspire by their leaves, and absorb by their roots, more than if they were exposed to the sun in a moister atmosphere.

Whatever doubt there may be concerning the precise causes of evaporations, there can be none whatever as to the power which sunlight has to cause the decomposition of carbonic acid, the fixing of the carbon, and the giving out of oxygen.

"If," says De Candolle, "two plants are exposed, one to darkness and the other to the sun, in close vessels, and in an atmosphere containing a known quantity of carbonic acid, and are removed at the end of twelve hours, we shall find that the first has diminished neither the quantity of oxygen nor of carbonic acid; and that in the second, on the contrary, the quantity of carbonic acid has diminished, while the quantity of free oxygen has increased in the same proportion. Or if we place two similar plants in closed vessels in the sun, the one in a vessel containing no carbonic acid, and the other in air which contains a known quantity of it, we shall find that the air in the first vessel has undergone no change, while that in the second will indicate an increase of oxygen proportioned to the quantity of carbonic acid which has disappeared; and if the experiment is conducted with sufficient care, we shall discover that the plant in question has gained a proportionable quantity of carbon. Therefore, the carbonic acid which has disappeared has given its oxygen to the air and its carbon to the plant, and this has been produced solely by the action of solar light."

However varied experiments may be, they all lead to the same result, and compel us to acknowledge the great importance of light to plants, in enabling them to digest the crude matter which they gain from the soil. In fact, there is nothing of which we have any certain knowledge that interferes with these conclusions. We see in practice that the more plants are exposed to light when growing naturally, the deeper is their green, the more robust their appearance, and the greater the abundance of their odours or resins; and we know that all the products to which these appearances are owing are highly carbonized. On the contrary, the less a plant is exposed to sunlight, the paler are its colours, the laxer its tissue, the fainter its smell, and the less its flavour. Hence it is that the most odoriferous herbs are found in greatest perfection in places or countries in which the sunlight is the strongest—as sweet herbs in Barbary and Palestine, Tobacco in Persia, and Hemp in the bright plains of extratropical Asia. The Peach, the Vine, and the Melon, also, no where acquire such a flavour as under the brilliant sun of Cashmere, Persia, Italy, and Spain.

This is not, however, a mere question of luxury, as odour or flavour may

be considered. The fixing of carbon by the action of light contributes in an eminent degree to the quality of timber—a point of no small importance to all countries. It is in a great degree to the carbon incorporated with the tissue, either in its own proper form, or as resinous or astringent matter, that the different quality in the timber of the same species of tree is principally owing. Isolated Oak trees, fully exposed to the influence of light, become a tougher and a more durable timber than the same species growing in dense forests; in the former case its tissue is solidified by the greater quantity of carbon fixed in the system during its growth. Thus we have every reason to believe that the brittle Wainscot Oak of the Black Forest is produced by the very same species as produces the tough and solid naval timber of Great Britain. Starch, again, in which carbon forms so large a proportion, and which, in the Potato, the Cassava, Corn, and other plants, ministers so largely to the nutriment of man, depends for its abundance essentially upon the presence of light. For this reason, Potatoes grown in darkness are, as we say, watery, in consequence of no starch being developed in them, and the quantity of nutrition or amylaceous matter they contain is in direct proportion to the quantity of light to which they are exposed. For this reason, when orchard-ground is under-cropped with potatoes, the quality of their tubers is never good; because the quantity of light intercepted by the leaves and branches of the orchard-trees prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the Potato-plant. Mr. Knight has turned his knowledge of this unquestionable fact to great account in his application of the principles of vegetable physiology to horticultural purposes.

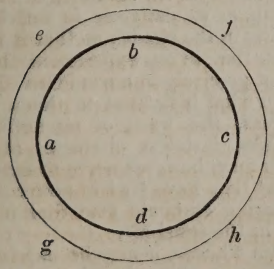
It is to the power which the sun's rays possess of decomposing carbonic acid, and fixing the residual carbon, that many of the directions which the parts of plants assume are ascribable. When, for instance, a branch first quits a stem, its own weight would give it a tendency downwards, if it were not for the effect of light from above, which solidifies the parts exposed to it. Let any one expose a green branch in such a manner that light strikes it only on one side; the tissue of that side will fix most carbon, will become harder, and will lengthen less; while the opposite will fix less carbon, be less hard, and will lengthen more; the consequence of which will be, that the illuminated side will contract, and pull the branch towards the light. This, if rightly considered, will of itself explain the uniform tendency of the green parts of plants to turn towards the light; and if it will not account for such phenomena as that of the Sunflower turning its flowers constantly to the sun, and following him in his course, as we find repeated by author after author, that circumstance is ascribable not to any defect in the explanations that have just been given, but *to the alleged phenomenon having no existence in nature.*

What, then, with the evaporation of the watery parts, the fixing of a part of the water, and the decomposition of carbonic acid, the crude sap of plants is changed from its original nature to the secretions which are peculiar to different species; but by what other means, unless by the specific action of the vital principle, are established the new proportions of oxygen, hydrogen, and carbon, and occasionally of nitrogen, which are necessary to form the acids, resins, gums, sugars, amylaceous alkaline, and other forms of matter which are met with in plants, is still unknown.

The deposit of these substances, and of the earthy, metallic and other extraneous materials which pass into the system of a plant, along with its fluid nutriment, gradually consolidates the tissue, cases over its sides, chokes up its intercellular passages, and prevents the organic membrane from performing its functions. When this happens, the part in which it occurs dies, or at least ceases to be capable of further action; and thus wood and bark become incapable of conveying fluid, and leaves fall from the branch that bears them. This, which is called the fall of the leaf, has always been a puzzling circumstance to account for. One man has assigned it to the rupture of the spiral vessels which connect the leaf with the stem; another has called it analogous to the sloughing of parts in animals, without pretending to explain the organic cause; others have simply said that leaves fall off because they are dead. Perhaps the following explanation may not be far removed from the truth. The space where the

base of a leaf is connected with a stem may be represented by the circle *a*, *b*, *c*, *d*, *fig.* 93. When both the leaf and stem are in a state of health, they continue to grow equally, the base of the leaf stretching and increasing in diameter as the circumference of the stem is enlarged in consequence of its distention by the wood which is forming within it; and it is obvious, that so long as this mutual adaptation goes on, the organic connexion between the leaf and stem will not be interrupted. But let the base of the leaf, *a*, *b*, *c*, *d*, lose its power of growth, in consequence of being killed by the deposit of foreign substances in it, the growth of that part of the stem which answers to this circle will not therefore be interrupted, but will go on growing, and in time will occupy the space described by the circle *e*, *f*, *g*, *h*. To effect this, all the parts inclosed within the circle *e*, *f*, *g*, *h* must become disjoined from those of the leaf comprehended within the circle *a*, *b*, *c*, *d*, and the inevitable consequence will be the separation of the two, when the leaf will drop off. What gives this explanation the greater appearance of probability is the well-known fact, that leaves do not drop off the stems of Endogens, which never increase in diameter; in such cases they simply perish and rot away. It must, however, be remembered, that whatever value there may be in this explanation of the fall of the leaf, it will by no means account for other instances of disarticulation between different organs, or different parts of the same organ; such as the separation of the upper half of the capsule of the Pimpernel (*fig.* 65 *b*) from the lower, the dropping in pieces of a

Fig. 93.



lomentaceous legume, the separation of the valves of a Cruciferous pod from their frame (*fig.* 68 *c*), and the like. The causes of these things are totally unknown.

Chapter V.

Of Respiration, and of the Effects of Vegetation upon the Atmosphere.

Under the name of respiration we shall include all that is connected with the inhaling and giving off of gaseous matter by plants.

This function is chiefly connected with the absorption of oxygen and carbonic acid, and their expiration. By a vast number of experiments, chemists have determined that the green parts of plants placed in the sun absorb carbonic acid from the atmosphere, and decompose it, giving back the oxygen; and that, at night, they absorb oxygen from the atmosphere, giving off carbonic acid; it is also probable that they part with a small quantity of carbonic acid during the day.

When the first observers remarked that, if green leaves were placed in water in the sunshine, bubbles of air were produced, it was not clear whether the gas originated from the leaves or the water; nor was it known that the bubbles might not be produced by air adhering to the leaves. None have conducted their researches into this curious subject with more care than Theodore de Saussure, Senebier, and De Candolle; the result of whose investigations is briefly this. Three conditions are necessary, in order to secure the disengagement of oxygen by leaves: firstly, the parts must be green; secondly, they must be exposed to the direct action of the solar rays; and, thirdly, there must be carbonic acid in the water.

The circumstance that green parts alone, with a few exceptions, are capable of giving off oxygen, sufficiently proves that it cannot result from what atmospheric air may adhere to the leaves under experiment; and Senebier ascertained that, if the green parts are exhausted of their air by the air-pump, they will nevertheless emit air-bubbles as usual when placed in water in the sunshine. That this is, in fact, a vital action, is proved by dead leaves, still green, having no power of emitting gaseous matter until they begin to decompose.

It is not sufficient to place leaves in bright light to procure the emission of

oxygen by their leaves in water; it must be under the direct rays of the sun. De Candolle found the purest daylight, the brightest lamplight, insufficient to produce the phenomenon: a very curious result, when we consider how large a part of vegetation is seldom exposed directly to the solar rays. Of course nothing like emission of oxygen would occur at night.

It is not even any kind of water in which oxygen will be evolved in the sunshine; neither boiled water, nor distilled water, nor that in which nitrogen, hydrogen, or even oxygen have been dissolved, will produce the result. But if a small quantity of carbonic acid is dissolved in the water, the green parts, stimulated by the sun, disengage oxygen. Various ingenious means have been contrived to prove this fact, and to show that the quantity of oxygen given out is proportioned to the quantity of carbonic acid decomposed; one of the prettiest experiments is the following, by De Candolle: He placed in the same cistern two inverted glasses, of which one (A), as well as the cistern itself, was filled with distilled water, and had a plant of Water-mint floating in it; the other glass (B) was filled with carbonic acid. The water of the cistern was protected from the action of the atmosphere by a deep layer of oil. The apparatus was exposed to the sun. The carbonic acid in the glass B diminished daily, as was obvious from the water rising in it; and at the same time there rose to the top of the glass A a quantity of oxygen, sensibly equal to the quantity of carbonic acid absorbed. During the twelve days that the experiment was continued, the Mint plant remained in good health; while, on the contrary, a similar plant, placed under a glass, filled with distilled water only, had disengaged no oxygen, and exhibited manifest signs of decomposition. The same experiment having been tried, only employing oxygen in the place of carbonic acid, no gas was disengaged in the glass that contained the Mint plant.

This is sufficient to show that the green parts of plants exposed to the sun decompose carbonic acid. By others, not less ingenious, it has been ascertained that the carbon which is the result becomes fixed in the plant itself. It has been found that Periwinkles growing where carbonic acid had access to them, gained carbon; while similar plants, in a situation cut off from the access of carbonic acid, not only gained no carbon, but lost a part of what they previously possessed.

If the green parts are placed in the dark, in a receiver full of atmospheric air, we find that the quantity of oxygen is perceptibly diminished. From this, and many other considerations, we are forced to conclude that oxygen is absorbed by plants at night. This gas does not, however, remain in the system of a plant in an elastic state, for neither the air-pump nor heat will disengage it; but it appears to incorporate itself with the tissue, since solar light readily disengages it. The inference therefore is, that it is absorbed at night, and combines with the carbon already existing, forming carbonic acid, and that the latter is decomposed by the sun, as has before been shown.

Other experiments show, that although the absorption of oxygen and the decomposition of carbonic acid are the principal phenomena of respiration, yet that a small quantity of carbonic acid is given off by the leaves both day and night. Hence Professor Burnet has suggested that, under the name of respiration, two distinct functions are confounded, and that respiration, properly so called, which consists in the extrication of carbonic acid, is incessantly in action; while digestion, which is indicated by the decomposition of carbonic acid and extrication of oxygen, takes place exclusively in daylight.

That the direct beams of the sun are not indispensable to it under ordinary circumstances is proved by the power of plants to form green matter, which is fixed carbon, without being exposed to the sun, as we daily see in individuals growing in the shade; so that it would appear that, in our experiments, plants are not precisely in a condition equivalent to what is natural to them. The paleness, the want of strength, the scentless, tasteless character of such plants may, however, serve to convince us that they have far less power of decomposing carbonic acid than if they grew in the sunshine.

From whence, it may be inquired, is the large quantity of carbonic acid obtained which is thus necessary to the support of plants? Certainly not from the atmosphere alone, for it does not

usually contain more than one part in two thousand of carbonic acid. There can be no doubt that this gas is supplied principally by the earth, in which it exists in great quantity; that a part is obtained from the atmosphere; and that a certain other portion results from the combination of the oxygen of the atmosphere with the carbon of vegetation; and it would seem as if a repeated decomposition and recomposition of carbonic acid was the principal phenomenon in respiration. When we consider how essential it is for roots to be near the surface of the soil, that is, within reach of atmospheric air, and that in all plants the principal part of the roots has a horizontal direction below the surface, we shall see at once the probability that this tendency, when we connect it with the preceding facts, is given them, in order that they may be favourably situated for the access of the carbonic acid, either formed in the soil by fermentation, or produced by the combination of the oxygen of the atmosphere with the carbon of the soil. Theodore de Saussure's experiments completely prove this.

Hence it appears, that while animals vitiate the atmosphere by respiring carbonic acid, plants purify it by absorbing it. It may be said, indeed, that they also deteriorate it by abstracting its oxygen: but it is to be remembered, that if they inhale it at night, they return it in the day-time; and Dr. Daubeny has ascertained that the slight diminution of oxygen, and increase of carbonic acid, which takes place during the night, bears no considerable proportion to the degree in which the contrary effect is observable during the day. Thus Providence provides a living check upon miasmata, and has admirably arranged that one of the kingdoms of nature should render and maintain the world in a state habitable by the other.

It has, indeed, been supposed by some French botanists, that in the beginning, the world had an atmosphere so highly charged with carbonic acid, as to be unfit for the respiration of any animals of a higher order than molluscs; that plants gradually purified it, depositing in the earth the carbon thus abstracted in the form of coal, till the air became fit to be breathed by reptiles, then by mammals, &c., and last of all by man. But although it is certain that carbonic acid is in so great a degree the nutriment of plants, and although Theodore de Saussure ascertained that, in the sunshine, plants thrive in an atmosphere containing twelve per cent. of carbonic acid, yet the same observer found that, in the shade, the smallest dose added to what is ordinarily present in the atmosphere was deleterious.

As plants part with carbonic acid and inhale oxygen at night, some persons have fancied that they must render the air of a room unwholesome; but if we remember that a single human being will vitiate the atmosphere infinitely more than a hundred plants, we shall not attach much importance to this opinion. If it is vitiated at all by flowers, it is by their powerful odours, which in many cases act upon the nerves, and so prove inconvenient to delicate persons.

What we now have seen of the action of the leaves and green parts of plants, will enable us to appreciate the adaptation of their internal structure to perform their functions. We have found them to consist of a number of little cells or bladders, so loosely cohering, that the air has room for free circulation between them; and that by the way in which they are arranged, they present the greatest possible surface to the action of the atmosphere. Although they are inclosed in a thick cuticle, yet they are provided with openings through it, called stomates, by means of which free admission for air is secured, and through which it may be expelled again with facility; when they are submersed, and are, consequently, neither exposed to irregularities of temperature nor of dryness in the air, they have no occasion for either cuticle or stomates, for the water in which they float carries the air dissolved in it to every part; and, consequently, submersed plants have neither. It is true that M. De Candolle entertains doubts whether the stomates are not rather organs of evaporation; but when we consider the relation they bear to the air-cavities in leaves, we can scarcely doubt that they are really respiratory organs; nor does it appear clear why they should not, in fact, perform the functions both of perspiration and respiration. If we hold a leaf of Laurustinus over a candle, so as to heat the air contained in it, without burning the

leaf itself, the air will be expelled through the stomates with such force as to extinguish the flame.

With regard to parts not green, which botanists usually call *coloured*, their function seems to be to absorb oxygen without fixing it, and they appear to possess no power of decomposing carbonic acid when they have formed it. Such is said to be the case with roots, old trunks, petals, stamens, ripe fruits, Mushrooms, and certain Lichens. A part of their carbonic acid escapes into the air, a part is dissolved in their fluids, especially in the roots, whence it passes upwards into the system. Flowers are said to replace a small part of the oxygen they abstract by an exhalation of nitrogen.

Chapter VI.

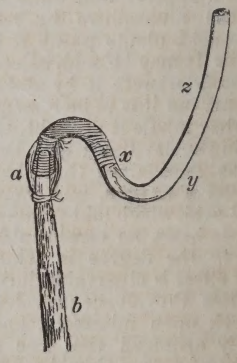
Of Circulation; or the Movements of Fluids in Plants.

Compared with that of animals, there is no such thing as a circulation in the fluid matter of vegetation; that is to say, a movement throughout the system from and to one common point has no existence. This would be impossible from the absence of any common seat of life, and from the exceedingly compound nature of a plant, which does not consist of a single system of growth, but, like a Polype, must be considered as composed of myriads; for each bud has a system of circulation, growth, respiration, and digestion of its own, and a plant is nothing but a great number of such systems combined under one common cuticle, and living in concert.

But although we cannot compare the movement of vegetable fluids to the circulation of the blood, yet it is undoubted that a constant, and sometimes a very powerful, motion takes place, by virtue of which the sap absorbed by the roots rises up the stem, passes into the leaves, flows back in an altered state into the bark, and thence descends towards the roots. Otherwise there would be no means by which the roots could support the leaves at such considerable distances as the spongelets and the tiny foliage are sometimes separated. In the Pines of North West America, for instance, leaves are supplied with food by spongelets which, by calculation, must be four hundred feet distant; and as such leaves are often not more than half an inch long, the force of motion in the sap must be very great, which will enable the leaves to derive support from a distance nearly ten thousand times greater than their own length. In fact, if we wound a tree during the leafing season, the rapid manner in which the sap will flow from the lower lip of the wound brings the phenomenon distinctly before our eyes.

The force with which the sap rises has been the subject of some curious experiments, one of the most instructive of which is the following of Hales, which we give in his own words:—"April the 6th, at 9 A.M., rain the evening before, I cut off a Vine on a southern aspect at *a* (*fig.* 94), 2 feet 9 inches from the ground; the remaining stem *a b* had no lateral branches, it was $\frac{3}{8}$ inch diameter; I fixed on it the mercurial gage *a y*. At 11 A.M. the mercury was risen to *z*, 15 inches higher than in the leg *x*, being pushed down at *x* by the force of the sap which came out of the stem at *a*.

Fig. 94.



"At 4 P.M. it was sunk an inch in leg *z y*. April 7th, at 8 A.M., was risen very little, a fog; at 11 A.M. 'tis 17 inches high, and the fog gone. April 10th, at 7 A.M., mercury 18 inches high; I then added more mercury, so as to make the surface *z* 23 inches higher than *x*; the sap retreated very little into the stem, upon this additional weight, which shows with what an absolute force it advances; at noon it was sunk one inch. April 11th, at 7 A.M., $24+\frac{1}{4}$ inches high, sunshine; at 7 P.M. 18 inches high. April 14th, at 7 A.M., $20+\frac{1}{4}$ inches high; at 9 A.M.

22+½, fine warm sunshine; here we see that the warm morning sun gives a fresh vigour to the sap. At 11 A.M. the same day, 16+½, the great perspiration of the stem makes it sink. April 16th, at 6 A.M., 19+½, rain; at 4 P.M. 13 inches. April 17th, at 11 A.M., 24+½ inch high, rain and warm; at 7 P.M. 29+½, fine, warm, rainy weather, which made the sap rise all day, there being little perspiration by reason of the rain. April 18th, at 7 A.M., 32+½ inches high, and would have risen higher if there had been more mercury in the guage; it being all forced into the leg *yz*. From this time to May 5th, the force gradually decreased. The greatest height of the mercury being 32+½ inches; the force of the sap was then equal to 36 feet 5+½ inches height of water. Here the force of the rising sap in the morning is plainly owing to the energy of the root and stem. In another like mercurial guage (fixed near the bottom of a Vine which ran 20 feet high), the mercury was raised by the force of the sap 38 inches, equal to 43 feet + 3 inches +⅓ height of water, which force is near five times greater than the force of the blood in the great crural artery of a horse; seven times greater than the force of the blood in the like artery of a dog; and eight times greater than the blood's force in the same artery of a fallow doe."—*Vegetable Statics*, p. 105.

Through what routes the sap passes is a more easy question to resolve. If we cut a stem through about the leafing season, we shall find the albumen, or sap-wood, discharging a great quantity of fluid; the heart wood less; and the bark none at all. If we simply make an incision into a tree, the sap-wood will give out sap in abundance from the lower lip of the wood; the bark none whatever. But if we examine the same parts in the same way at a later period of the year, the upper lip of the wounded bark will discharge a quantity of fluid, but the lower none. Vary these experiments as we please, and the result is always the same. Hence we are forced to conclude, that in Exogens the sap rises through the sap-wood, and descends through the bark; not, however, through the sap-wood exclusively, but through all the parts of the wood which are not absolutely choked up with deposited matter. Of its course, in Endogens and Acrogens, we know nothing worth stating.

But if we cut through the wood of a growing tree obliquely, so as to form a tangental line within its circumference, we shall remark a quantity of fluid oozing from the face of the wound, especially on the face next the bark; and if the tree is preserved in health, the matter from the latter part will continue to ooze out during the remainder of the season, forming a crust of elaborated matter. Hence we must conclude, that, independently of the ascent through the sap-wood, and the descent through the bark, there must be also a lateral transmission from the bark inwards.

What has just been stated belongs to the unquestionable facts in Vegetable Physiology; through what particular forms of tissue sap moves is far less certain. It is not to be doubted that the sap ascends by the woody tissue, as is proved by coloured infusions which are forced to ascend by artificial means; but whether through the tubes of woody fibre, or by the intercellular passages, has not been, and probably cannot be, decided. It is also a question whether it ascends or not by the dotted ducts and the vessels; there can be no doubt that these parts, with the exception of the spiral vessel, appear to be filled with fluid when the sap is in its most rapid course; but it is equally certain that the dotted ducts, at least, are empty afterwards: are we to conclude that these forms of tissue perform one function in the spring, and another in the autumn; or are we rather to suppose that the appearance of being filled with fluid, which they exhibit in the spring, is owing to the wounded vessels in their neighbourhood overflowing into them when cut through? There is no satisfactory answer to this as yet upon record. In its downward descent it may be reasonably assumed that both the fibrous and cellular parts of the tissue assist in its conveyance; but it is to be suspected, that although we speak of them in this general manner, yet that in reality these two forms of tissue do convey different kinds of fluid; because we find certain secretions most abundant in the bark, such as gum, and others, such as astringent matter, equally abundant in both the wood and the bark. Perhaps the woody fibre, which is not directly connected with the medul-

lary processes, brings downwards gummy and similar matters, while others pass freely down the cellular tissue. The medullary processes undoubtedly carry on the horizontal transmission, and are the means by which the circumference communicates with the centre of a tree. This their position, the direction of their tissue, and their appearance during the growing season, render sufficiently manifest.

From the latest experiments, and the best conducted arguments, it would seem that the cause of the movement of the sap upwards is, as far as we have any means of assigning an immediate cause to the phenomenon, the development of the buds and leaves. When a young bud, or a leaf, is first excited to growth in the spring, the fluids it contains are increased in density by evaporation; endosmose immediately takes place between it and the tissue below it, which latter parts with the thinnest portion of its contents, and then acts by endosmose upon the tissue below it, and thus the whole chord of vegetation is set in vibration, if we may so express it, from the extremity of the branches to the points of the root; the moment the spongelets are affected, the fluid in the soil is attracted through their sides, and thus a complete motion throughout the system is established. Hence the leafing of trees is not the effect of the ascent of the sap, as it is usually thought to be, but the cause of it. It may be supposed that the mere effect of gravitation will carry downwards the sap in its densest state after it has ceased to obey the attraction of the leaves, and that it will descend by simple filtration till it reaches the roots; but how we are to account for its lateral transmission through the medullary rays is still unknown.

The sap of plants then ascends in its crude state through the sap-wood, and reaches the leaves; is there finally decomposed, assimilated, and inspissated; is discharged back into the bark; settles downwards towards the roots; and passes off laterally by the medullary passages into the heart-wood. Heart-wood is, in truth, nothing but sap-wood consolidated by the addition of secreted matter, and may always be restored to the state of sap-wood by any solvent of the secreted matter. Ebony, for example, is jet-black; when young it is whitish, and it only gains colour as the black substance is generated in the leaves discharged into the bark, impelled into the medullary processes, and by them deposited in the wood. Plunge a piece of ebony into hot nitric acid for a few minutes, the colouring matter will be discharged, and the tissue will be restored to the state of sap-wood.

Besides this kind of general motion, which seems indispensable to the very existence of a plant, and which our reason would have told us must exist, if our experiments failed in revealing it to our sight, there is another which no force of reasoning could have led us to expect, and which is altogether of a local and partial character. It was originally ascertained by Amici, that in the Chara plant there is a curious rotatory motion in the fluid of each cell of which that plant consists. It may be described as a revolving movement round the inside of each cell, ascending on one side and descending on the other, with an occasional irregular interchange of matter between the sides; and, what is very curious, the ascending current is uniformly on that side of each cell which is most remote from the axis of growth, and consequently the descending current is on the side nearest the axis. Some excellent observations upon this phenomenon, by Messrs. Solly, Slack and Varley, will be found in the *Transactions of the Society of Arts*, vol. xlix. to which we would especially direct the attention of the reader. After finding it in Chara, and its kindred genus Nitella, it was discovered in the cells of the Frogbit (Hydrocharis Morsus Ranæ), a common water-plant, and in the hairs of so many species, that we are led to suspect it to be a phenomenon by no means confined to the cases in which it has been observed, but of universal occurrence; and that it may be connected with the assimilations of fluid and gaseous matter by the tissue: it may, in fact, be a movement of digestion, going on by night as well as by day. A vial-microscope, for the express purpose of showing these motions, has been ingeniously contrived by Mr. Varley, and may be procured from the optical-instrument makers. It is fully described in the 50th volume of the *Transactions of the Society of Arts.*

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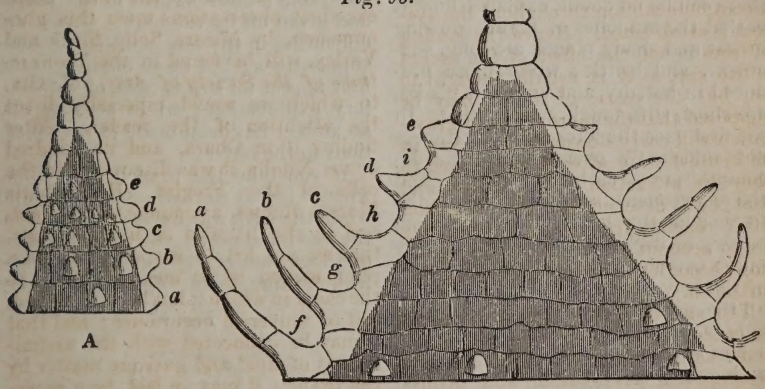
Chapter VII.

Of the Growth of Plants.

Concerning the precise manner in which new cells or tubes of tissue are generated, little very satisfactory is known. By some it has been fancied that they were produced by the extrication of gaseous matter in solidifiable mucus; others have hardily asserted that the minute green globules, which we find sticking to the sides of tissue, are young cells or tubes, and that they grow from their mother-cells as seeds grow from their placenta; suffice it to say that these are mere *assertions*. All that we really know about the matter is this: that in Chara and Nitella, young cells appear like buds at the point, or axils of older cells, and gradually lengthen out into the tubular form peculiar to those plants; and that in Marchantia polymorpha they have been seen, by Mirbel, to form in a somewhat similar manner. He states that a lobe of that plant, such as is represented at *fig.* 95, A, changed to such a lobe as is shown at B, which he explains in the following manner. The young lobe, A, presents on its surface, at its widest part, five rows, *a*, *b*, *c*, *d*, *e*, of cells, arranged parallel to its basis. The two cells which terminate each row, one to the right, the other to the left, are inflated and conical, and, consequently, form two marginal projections. The five rows, *a*, *b*, *c*, *d*, *e*, are united without intermediate tissue. The older lobe, *fig.* 95, B, shows nine rows, *a*, *f*, *b*, *g*, *c*, *h*, *d*, *i*, *e*, of cells, placed parallel with its base. Five of these rows, *a*, *b*, *c*, *d*, *e*, terminate, right and left, by a marginal cone, formed of a single cell, or, which is more usual, of two, three, or four cells attached end to end. The four other rows of cells, *f*, *g*, *h*, *i*, are placed between the first, so as to alternate with them, and they have no marginal appendages. It is evident, notwithstanding the augmentation of the number of the cells, that the five rows, *a*, *b*, *c*, *d*, *e*, of *fig.* 95, B, and their conical appendages, represent the five rows of cells, *a*, *b*, *c*, *d*, *e*, of *fig.* 95, A, with their marginal projections. But the four alternate rows, *f*, *g*, *h*, *i*, of *fig.* 95, B, have no representatives in A; and as the latter is the younger of the two, we must conclude that the four alternate rows of the other lobe were developed subsequently to the formation of the five rows with appendages.

Fig. 95.



We have quoted this at full length because it appears to be the most important, the most clearly demonstrated, and, it might be added, the only tangible observation that has yet been made concerning the development of tissue. If it does not explain the increase of solids, such as stems and the like, it seems to be, at least, applicable to leaves and all their organs; the unevenness of whose edges, *in all cases* seems to increase the probability of their really being developed upon this plan.

When a branch or a young plant first begins to lengthen, it is merely a bud, reposing upon a certain quantity of cellular tissue, which in Exogens is pith, and which is always highly charged with fluid. The moment light

and heat are sufficiently powerful to produce a decomposition of carbonic acid and a thickening of the fluids, endosmose is set in action, and produces a current from below upwards, which is variable in intensity in different species, but which always acts as a force fr m behind, impelling the tissue in the direction of its own current. The tissue of the buds, young and soft, and scarcely at all solidified by the deposit of carbonaceous, earthy, or other matters, yields freely to the impulse, stretches, lengthens, and grows, preserving its rectilinear direction, so far as is practicable, considering the action of the light upon it, and the unequal carbonization of its sides. But the instant the leaves begin to develope, they decompose carbonic acid, assimilate the fluids sent into them from the stem, evaporate the superfluous moisture, and returning the inspissated sap downwards, gradually harden the tissue of the circumference. Thus, as De Candolle well remarks, a branch, during its increase in length, is under the influence of two opposing forces; the one, from below, softening its tissue and forcing it to lengthen; the other, from above, solidifying it and rendering it incapable of elongation. This fact, about which there can be no doubt, explains how it is that the branches of plants growing in wet and shady places, are long, succulent, and brittle; while those produced in hot, dry, and sunburnt places, are short, stiff, tough, and stunted. In the first case the force of elongation is not sufficiently overcome by the decomposition of carbonic acid, &c., and the consequent solidification of the tissue; in the latter, the force from below, in itself is feeble, and is very much overcome by the powerful action of the leaves, and the degree in which all the parts become hardened. It is only when neither shade nor sunlight are in excess that the pliable, tough, and evenly-formed branches of trees are produced. When the force from below is entirely overcome by the force from above, branches cease to grow.

In general, plants increase but little in diameter till their full annual length is nearly attained; but as soon as that has happened, they enlarge sensibly, and often rapidly, forming woody matter. In what manner this is brought about has been a fertile subject of controversy, in which physiologists have scarcely been unanimous in anything till lately, when they seem to agree in admitting this, that wood is sent downwards from the leaves. If you tie a ligature round the branch of an Exogen, the diameter above the ligature will increase, that below it will remain without alteration. And if you wound an Exogen by cutting off a large patch of its bark, new woody matter will form upon the upper lip of the wound, and no where else.

Fig. 96.

This point being settled, opinions have been pretty generally divided between two inferences; the one, that wood is organized matter, sent directly downwards from the leaves and buds; the other, that it is produced by the organizable matter formed in the leaves and given off by the bark. There are difficulties in the way of either of these suppositions; but those relating to the first appear all susceptible of satisfactory explanation; while nothing like an answer has been made to the objections to the latter.

If you take the branch of a Lilac when it is just clothed with leaves, and while the bark will freely separate from the wood, and peel it, you will find ridges of tubes passing downwards from each leaf, turning aside (*fig.* 97) at every

Fig. 97.

little obstruction, re-uniting after the obstacle is passed, and, together, forming a firm fibrous case to the subjacent

wood of the previous year. In others, the fibres may be traced in like manner from the leaves; but instead of running parallel with each other, they cross each other diagonally, and form a sort of lozenge work. This is wholly inexplicable upon the supposition that wood is deposited by the bark; but it is clearly intelligible if the wood is regarded as an organic emanation from the bases of the leaves. Again, in Endogens, the woody fibres may be distinctly traced into the leaves, from which it is plain that they originate; and in this case, at least, it is manifest that the woody bundles cannot be organized matter deposited by the bark; for they are in the centre, while the bark is at the circumference. We therefore cannot resist the conclusion that wood is organic matter emitted from the bases of the leaves, passing partially down the bark, and rendering the liber fibrous, but principally confined to the wood.

Du Petit Thouars, indeed, went so far as to assert that wood is, in fact, composed of the roots of buds and leaves, inclosed below a common bark, and that plants are, in fact, communities of individuals, each having an independent existence, although combined in one common system. When we consider that buds have the power of emitting roots when cut off the plant on which they grew; that in the Dragon tree if one bud vegetates, upon a trunk otherwise dead, as sometimes happens, the bud, having no longer a series of vital systems with which it may combine, sends out undoubted roots beneath the bark, instead of the woody fibres that it would have emitted under ordinary circumstances; and that, in other cases, when wood has died, the living buds have formed a sort of entangled sheath of roots by the fibrous matter they have sent downwards; when we seriously consider these things, it is impossible not to admire the genius which led Du Petit Thouars to advance so bold a doctrine, and difficult not to assent to its truth.

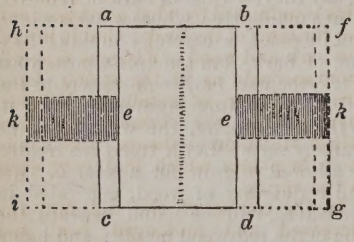
Without, however, embarrassing ourselves with this speculation, which is not of much practical importance, it may be safely asserted that there is no possibility of accounting for all the phenomena connected with the formation of wood, without understanding it to be produced by organic matter proceeding directly from the buds and leaves.

We must, then, adopt the following theory of vegetable growth, which, we believe, will be found conformable to admitted facts, in all the divisions of the vegetable kingdom. A plant is a mass of cellular tissue, capable of expansion and growth in all directions. When there is no leafy system, growth is indefinite, and not carried on in any particular direction, and no woody system is formed; but when leaves are developed, they send their organic fibres down through the mass of cellular substance, and arrange them sometimes in one way, sometimes in another, according to the specific powers of a plant. Upon this supposition the stem of a woody plant will be composed of two essentially distinct systems; the one cellular, constituting the pith, the principal part of the bark, and the medullary processes (if an Exogen), and capable of growth in all directions; the other fibro-vascular, comprising the wood and a part of the bark, and capable of growth longitudinally only. It will be found that this will answer all the objections which have been made to wood being an organic emanation of the leaves.

The following is a favourite argument with those who believe wood to be a superficial deposit from the bark. If, say they, a ring of bark is removed from a maple-tree, whose wood is white, and its place is carefully supplied by a ring of bark from a maple whose wood is red, the new bark will adhere to the old wood, uniting organically with it, so that, externally, the wound will be scarcely seen. Let a tree thus treated be allowed to grow for a year or two, and a quantity of wood, generated in the leaves, will be found beneath the ring of the red-wood maple; and being the produce of leaves and buds furnishing white wood, it should be white also, if, indeed, those organs really have the power of generating wood as is supposed. But it will be found that red wood will have been formed below the red bark; therefore wood is a deposit from the bark. This is one of those forms of fallacious reasoning which are the best calculated to catch the unwary, but which will not bear examination. The facts stated in it are true, but the inference is false, as will be intelligible from the following

diagram:—Let the letters *a*, *b*, *c*, *d* (*fig.* 98) represent a section of a tree, round whose wood (*a c* and *b d*) a ring of red bark (*e e*) has been made to grow. As soon as the diameter of such a piece of wood commences to increase, it is by a double action; the first arising from the *horizontal* expansion of the cellular system of the bark and medullary processes, which will remove the bark, *a*, *b*, *c*, *d* to *f*, *g*, *h*, *i*; and consequently the red ring *e* will advance to *k*; the second depends upon the introduction of the fibro-vascular system of the wood *longitudinally* among the horizontal system, to make room for the former of which, the latter is constantly growing. Now the colour of young wood depends entirely, and of old wood in a great degree, upon the colour of the medullary processes or horizontal cellular system; and consequently as the ring of red bark, which is a part of the same system, has grown outwards (that is from *e* to *k*) as the tree has increased in diameter, it would necessarily form a zone of red matter below it; and this would not be in the least interfered with in appearance by the new wood descending from above, because the latter, being colourless, would derive its colour from the horizontal system of the medullary rays, through which it would pass in its descent.

Fig. 98.



In like manner all other objections, however plausible, which have as yet been made to this view of the origin of wood, are to be answered with equal facility.

It is not, perhaps, of any practical importance to ascertain which theory of the origin of wood is the most correct, now that physiologists are, at all events, agreed upon its being produced in some way by the action of leaves freely exposed to sun or bright light. And this is abundantly sufficient to show the cultivators of trees the great importance of thinning their plantations carefully, without having recourse to severe pruning, which necessarily diminishes the power of the plant to form wood, because it deprives it of the leaves by which exclusively wood is generated.

Chapter VIII.

Of the Relation of Vegetation to Seasons.

Repose from growth seems periodically necessary to most plants, and accordingly we find there is no country without a season of growth and a season of rest—whether they are called by the name of winter and summer, or rainy season and dry season. This fact is connected with several considerations to which we have not yet adverted. What is about to be said has reference to the seasons of the North of Europe it is left to the reader to apply the ob servations to the climate of other parts of the world.

In the winter, we commonly say that all vegetation is at rest, that the sap ceases to flow, new parts to be developed, and old parts to enlarge. But this is not exactly true. It appears, from experiment, that vegetation is at all times more or less active; and that we ought to say, that it is languid in winter, and energetic in the spring and summer. The fact of many plants retaining their leaves, of others swelling their buds, and of all forming an addition more o less considerable to the points of their roots during winter, sufficiently attest the movement of the fluids, and the existence of vegetation even at that season. This is further proved by the well-known fact, that trees planted in the autumn become turgid with the fluid absorbed by their roots during winter; and as it appears from the French newspapers, by some recent experiments of M. Biot, who is represented to have succeeded in obtaining a flow of the sap from certain trees in mid-winter.

But whatever power of attracting sap by its roots a plant may possess during winter, it is obvious that it has little means of parting with any part of it again by evaporation at that period of the year; so that during the winter the whole of the tissue must gradually acquire a state of turgidity which will go on increasing till the leaves and new branches are developed

and carry off the sap, or decompose and assimilate it.

This turgid state is eminently favourable to rapid growth when vegetation once resumes its activity; for it acts as a force from behind, which continually presses upon the new-born tissue, and causes it to expand. It is well known that after very long winters, or when a plant has been prevented by artificial means from shooting at its usual season, its branches and leaves are developed with extraordinary vigour; a circumstance which has been ascribed to *accumulated irritability*, but which is in fact owing to the turgid state of the tissue.

It is when the temperature of the air is raised sufficiently high, that the vital energy of a plant is excited, and buds are developed with their leaves. Light has certainly nothing to do with this phenomenon, although it afterwards colours and consolidates the young parts; for if a plant is exposed to an elevated temperature, in total darkness, its growth takes place as if in the light. The common experiment of introducing into a hothouse the branch of a Vine growing in the open air, is another familiar illustration of this fact: the temperature of the hothouse excites the buds into action, they immediately attract fluid from beneath them, and thus the whole system is put in motion, although the Vine-plant may be exposed beyond the house to all the inclemency of winter. De Candolle has proved by a simple experiment, that in such a case as this the fluid consumed by the young leaves is really attracted from out of the cold earth, and not absorbed from the atmosphere of the hothouse. If you select a tree with two principal branches, and two principal roots to correspond with them, and adapt to each root in the earth a bottle of water, you will find that the bottle that corresponds with the branch in the hothouse will be quickly emptied, while that which is connected with the branch in the open air remains nearly full. It may be supposed that in a natural state of things a corresponding effect is produced upon the roots by the warmth of the surface of the soil, and that they also are stimulated into activity; but it is doubtful whether this amounts to much, if, indeed, it is of any importance whatever: for provided only the earth is not frozen, it appears from experiments that heat applied to the branches alone is quite sufficient to determine and maintain all the phenomena of growth.

Once set in action, the branches of a tree go on growing according to the laws which have now been explained. They and their leaves, by degrees, gain their full growth; bark and wood separate, and cambium deposited between them; the leaves decompose the fluid they receive, send their fibres down within the substance of the branches, gradually secrete the substances peculiar to each particular species, and transfer them to the bark; and finally, becoming clogged at every pore by the earthy and carbonaceous matters that are deposited during the processes of digestion and evaporation, cease to act efficiently as leaves. In this state they are principally protectors of the young buds in their axils. If the latter have been formed very early, they are so far advanced in their growth by the middle of the summer, that they have already arrived at the same state as later-formed buds will be in at the commencement of another spring. Acted upon by the temperature of the season, they develop and call into play the same class of phenomena as took place in the beginning of the spring: the sap, which had become languid as the leaves became impotent, is again stimulated to a rapid movement, and is secreted anew in increased quantity. This is indicated by what gardeners call the running of the bark; that is to say, the bark and wood of Exogens separate spontaneously as in the spring, depositing a layer of cambium between them. Thus are formed what are called Midsummer-shoots, which only occur in plants which bud very early in the spring.

In the course of the autumn, the increased and prolonged heat and drought complete the destruction of the leaves, which had already begun to languish: all their vital actions are destroyed by the quantity of foreign matter with which their cells, their stomates, their vessels, and their intercellular passages are filled, and they drop off.

At this time a plant is nearly exhausted of its fluid sap, the watery portion of which had exhaled during the summer and autumn: all the parts are dry and solidified, so as to suffer little from evaporation; and the roots themselves, having for some time

been but feebly in action, are firm and not liable to be easily broken; everything is in a state of languor, and prepared to renovate the enfeebled powers of the plant by the slow and gradual absorption of fluid during the winter.

It is in the autumn, then, that both theory and practice direct us to transplant trees. At that season every circumstance concurs to render the operation practicable; but if we wait till the spring, the spongelets which form during winter are likely to be destroyed, and many causes may call the already turgid plant into growth, before the roots have had time to form new spongelets.

The seasons of growth and repose are so essential to vegetation, that, as is familiar to all gardeners, it is scarcely possible to prevent plants preparing themselves for their annual changes, whatever artificial means may be employed to maintain them in a uniform atmosphere, and to protect them from those causes which usually bring about repose; and this is certain, that if we can succeed in preventing the cessation of growth, the plants which are the subject of the experiment uniformly, in the end, fall victims to the forced and unnatural condition in which they are maintained.

If annual changes in their condition are requisite to the well-being of plants, so in like manner are the diurnal changes of light and darkness. If plants were kept incessantly growing in light, they would be perpetually decomposing carbonic acid, and would, in consequence, become so stunted, that there could be no such thing as a tree, as is actually the case in the polar regions. If, on the contrary, they grow in constant darkness, their tissue becomes excessively lengthened and weak, no decomposition of carbonic acid takes place, none of the parts acquire solidity and vigour, and finally they perish. But under natural circumstances, plants, which in the day become exhausted by the decomposition of carbonic acid, and by the emptying of their tissue by evaporation, repair their forces at night by inhaling oxygen copiously, and so forming a new supply of carbonic acid, and by absorbing moisture from the earth and air without the loss of any portion of it.

Such being the case, we must conclude that plants grow chiefly by day, and this is conformable to the few observations that have been made upon the subject. Meyer found the stem of a Belladonna Lily, and plants of Wheat and Barley, grow by day nearly twice as fast as at night; and Mulder states that he has arrived at a similar result in watching the development of other plants.

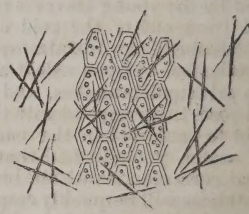
Chapter IX.

Of Vegetable Secretions.

One of the most important consequences of the decomposition and assimilation of their sap by plants is the formation of various secretions which are often peculiar to particular species. The production of these we must of necessity ascribe to the varied powers of the vital principle, for we cannot otherwise conceive in what manner the unelaborated fluids of the earth, or the gases mixed with the atmosphere, are converted to such a prodigious number of different products, by the uniform action of phenomena which are common to all plants.

These secretions are what give hardness and durability to wood, (while their absence renders it perishable,) flavour to fruit, and odour to flowers; which form the bitterness, acidity, or acridity of some, and the mucilaginous, farinaceous, saccharine, and other qualities of other species. Occasionally they may be perceived by the eye, assisted by the microscope, formed in regular crystals, having an acicular or prismatic figure, when they are called *raphides* (*fig.* 91); but most commonly

Fig. 91



they are amorphous and confounded with the tissue, or exist only in a fluid state. The nature and chemical proportions of these substances concern botany but little, and therefore a detailed account of them must be sought in the works of chemists. They are, however, in some things so intimately mixed up with physiological considerations as to require a short notice.

Pure vegetable secretions, of whatever kind, must, as has been already

shown, be the result of the combination of water and carbonic acid; that is, they must consist of the elements of water, with the addition of a variable amount of carbon; to which must be added nitrogen in some cases. And thus of an hundred and sixty-three distinct principles, which chemists have analyzed in the vegetable kingdom, there is not one of which oxygen, hydrogen, and carbon are not the elements; twenty-eight of them only having been found to contain nitrogen. In many cases the proportions in which these elements are combined are so similar in different principles, as in gum, starch, sugar, and lignine, that a very little change in the circumstances under which they are produced will suffice to convert the one into the other, so that they have even been considered as being all varieties of sugar itself. It is probable that all of this class, which De Candolle calls *hydrocarbonates*, are principally destined as nutrients of the young parts, and that they ought to be distinguished in regard to their functions from the acids, resins, alkalies, oils, and other secretions, which have apparently nothing to do with nutrition. They will accordingly be treated of separately in this place.

§ 1.—*Nutritious Secretions.*

Of the hydrocarbonates *gum* is the most common; it is found in the bark and wood of all plants in some proportion, and in many in great abundance. In the Cherry, the Arabian Acacia, the Tragacanth plant, and all those others which are called gum trees, it flows out in plenty when their bark is wounded, or when the surface of it cracks. The mucilage with which the sap is mingled immediately upon its introduction into the roots, and which is perhaps universal throughout the vegetable kingdom, and the jelly of the Grape, the Gooseberry, and other succulent fruits, are mere forms of gum. In short, the substance, being in reality nothing more than condensed water and carbon, is exactly what would be formed in common by all leaves, independently of the special power which different species may possess of secreting peculiar substances in addition.

Fæcula or *Starch*, different as it is vulgarly considered, seems to be really little more than gum divided into minute portions, each of which is inclosed in a cell of tissue; and it is said to be the latter only which is coloured blue by iodine. It is converted into grape-sugar by the addition of acids, and alkalies render it soluble. While gum itself may be considered the nutrient principle of vegetation, lying freely among the system of a plant, and constantly in action, starch is apparently the same substance stored up in such a manner as not to be readily soluble in the water of vegetation; and this, as De Candolle well observes, appears to agree very well with the office that starch has to perform in the vegetable economy, namely, that of forming a reservoir of nutritious matter, which is to be consumed in supporting a plant at particular periods. Thus we find it stored up—1. in the albumen of Corn, of the Buckwheat, and of a multitude of other plants; 2. in fleshy cotyledons, such as those of the Bean and the Pea, which like albumen are magazines of food for the support of the embryo plant; 3. in tubers intended to nourish young shoots, as in the Potato, the Jerusalem Artichoke, the Arrow-root plant, &c.; 4. in all fleshy roots which have to furnish food to the young stems when they first begin to grow, as in Briony, and in the Inula Helenium, which furnishes the starch called inuline; 5. in all bulbs, or root-stocks having a similar destination; 5. in the centre of the stems of endogens, as in the Sago palm, which is a reservoir of food for the leaves when they first begin to grow; 6. in the receptacles of such plants as the Artichoke, where it acts as food for the young flowers; and in the liber of some trees, as the Pine and the Birch, and in the rind of certain fruits, such as the Date, the Bread-fruit, &c.

In all these cases the starch is either capable of supplying food to the young parts of the plant, or may be supposed to be provided for the sustenance of man. That the former is its more immediate destination is probable from its continuing to increase during the latter part of the year when the plant is preparing a fresh supply, reaching its maximum when the plant has ceased to grow, remaining stationary during winter, and rapidly diminishing with the growth of the young shoots in spring. Thus it is stated in a French agricultural work, that 100lbs. of Potatoes contained the following proportions of starch:—

August . . .	10lbs.
September . .	14½
October . . .	17

March	17lbs.
April	13¾
May	10

In what way starch is adapted to the power which plants possess of absorption is not by any means clear. We know that it is only soluble at a temperature little below that of boiling water, when the organic integument of each little grain bursts, and allows the gummy matter it contains to flow out; but we have no such temperature in nature, not even in germination. De Candolle suggests that the action of several substances which exist along with starch, such as tannin and alkaline matters, may, in particular cases, cause a rupture of the integument, and liberate the gummy matter.

Sugar may be considered as starch, with an addition of oxygen, and consequently we find that the simple absorption of oxygen by seeds, when germinating, is sufficient to change their starch into sugar. Thus Barley is converted into Malt, by being forced to grow in the dark; and we find the fæcula that is present in flowers before they expand, converted into honey by the excessive absorption of oxygen which then takes place (see Chapters X. and XIII.) Like most of the secretions of plants, it is produced in greater quantity in southern than in northern latitudes. The Sugar-cane is scarcely sweet in our stoves, the richest Figs and Grapes that can be produced by artificial means in England will bear no comparison with those of the Mediterranean; and while the Chestnuts of the south of France contain as much as fourteen per cent. of crystallizable sugar, those of the north of Europe are almost sugarless. Is this owing to temperature? We think not; for the mean heat of a forcing-house in England is greater than that of the Levant. It is rather to the subtle and incomprehensible agency of light, which we have no means of imitating, that those important differences are to be ascribed. Sugar, like starch, appears to be intended for the nutrition of young organs; we find it abundantly in the ascending sap, whence it is transferred to the leaves; it is formed out of starch during germination for the support of the embryo plant, and during flowering for the food of the fertilizing organs; and it is carried off from the roots of herbaceous plants by the new leaves when they sprout in the spring. The Beet-root, for instance, rich as it is in sugar at the end of autumn, contains scarcely any after the leaves have been growing a short time in the spring; and the same is the case with Turnips and similar roots.

As gum, starch, and sugar seem to be the great nutrient principles of vegetation, it would be supposed that *lignine*, which is the result of their organization, must be extremely similar to them in composition. And such is really the fact, as will be obvious from a comparison of their chemical analysis as furnished by Gay Lussac and Thenard.

	Carbon.	Oxygen.	Hydroge
Gum	42·23	50·84	6·93
Starch	43·55	49·68	6·77
Sugar (of the cane)	42·27	50·63	6·90
Lignine	52·00	41·25	5·75

Lignine, therefore, differs from gum, starch, and sugar, principally in its elements consisting of a larger proportion of carbon; and it is not improbable that the quality of timber depends, to a considerable extent, upon the amount of its carbon; for although but few researches have yet been made into this curious question, yet as far as they go they seem to indicate such to be the fact. De Candolle gives the following proportions of carbon from the works of Gay Lussac and Thenard, and of Prout:—

Cormonna Wood	55	per cent.
Iron Wood	53·44	
Oak	52·53	
Beech	51·45	
Box	50	
Willow	49·80	

From these and similar considerations of the nature of the nutritious secretions of plants we may draw the following conclusions:—The rising sap passes into the leaves charged with carbonic acid, or matter capable of being converted into it; it loses a large proportion of its water by evaporation, and of its oxygen by the decomposition of its carbonic acid, and thus becomes reduced to carbon and water in an inspissated state, which is gum when free, and lignine when fixed. From the lignine is organized the tissue, among which the gum circulates for its support and consolidation, and within which it is also enclosed, and elaborated into various other principles, remaining as starch when but little changed. A portion of the gum settles

downwards through the stem: that part which is in the bark, being intercepted by no opposing current, finds its way down into the roots; such other part as finds itself in the alburnum is caught by the ascending current of sap, dissolved in it, and carried again into the leaves, there to undergo changes similar to what it had previously experienced. Whenever the gum meets in its course with cells that are empty, it is absorbed by them, and becomes subject to their special vital powers, changing to the principles which each particular species or organ has the property of elaborating, and the most readily to those which, like sugar, have the greatest chemical resemblance to itself.

§ 2.—*Special Secretions.*

Besides the secretions just spoken of, there are many others which are diffused through the system of certain plants, but which neither appear to contribute to the process of nutrition, nor enter into the general plan of vegetation, but are confined to particular species. They may be classed under the heads of milky fluids, resins, volatile oils, and fixed oils.

Milky fluids are generally characteristic of certain natural groups of plants, existing in every species, if in any; as is the case in Euphorbiaceous, Apocyneous, Papaveraceous, and other plants. When such are wounded, the milky fluids are forced out from both lips of the wound, showing that it is discharged in consequence of a contraction of the tubes or cavities in which it lies. These latter are of various kinds: sometimes they are long, thin-sided tubes, resembling the intestine of an animal; and sometimes they are rows of thick-sided cubical cells, such as are represented at *fig.* 90 *c*. By Schultz and Meyen, indeed, they are described as vessels of a particular kind, which the former calls *vital;* but there is every reason to believe that some error of importance is connected with their observations; for no one in this country has yet been able to discover what those gentlemen talk of having seen. Milk is usually white; but it is frequently orange, as in Celandine and the Gamboge tree; and it is occasionally crimson: in common Purslane it is said to be brownish-green. De Candolle distinguishes three sorts of milky fluid:—1. That in which caoutchouc is present. This is most common in plants of hot latitudes, hardly existing in the temperate zone under natural circumstances. It is most abundant in certain Apocyneous plants, such as Urceola elastica and Vahea Madagascariensis, which furnish the India rubber of India; and in some Euphorbiaceous species, such as Hevea Guianensis, or Artocarpeous ones, like Ficus elastica, from which that of other tropical countries is obtained. These are usually acrid and poisonous, although they are occasionally wholesome when the parts are young and have been exposed to heat. 2. Narcotic milk, in which opium is an essential ingredient, such as is met with in Poppies; and 3. A sort, of which fibrine is a principal component. This substance, which is very like animal fibrine, is characteristic of the milk of the Papaw-tree, and of the Cow-tree, whose milk is said, besides fibrine, to contain half its weight of vegetable wax.

When plants whose juice is milky are employed for food, any method which either prevents the formation of the milkiness, or by which it is removed when formed, is found effectual to render them then a safe aliment. Blanching, in particular, is attended to a certainty with the effect of removing noxious qualities, inasmuch as milk, like all other secretions, can only be formed when the leaves are fully exposed to light: the same thing happens when plants are very young, when they have not had time to elaborate their secretions, by attending to which the peasants of Languedoc are said to eat young Wild Poppies with impunity, and further, as it is through the bark that such secretions descend, any part of the wood will be harmless in plants whose milky bark is poisonous. Thus the peasants of Teneriffe are enabled to suck the cooling lymph from the wood of a highly poisonous plant called Euphorbia Canariensis, by first stripping off its bark.

Resins are common in the bark of several natural orders, especially of coniferous plants; they are also met with in the wood, and even in the pith. They have no tissue specially provided for their reception; but form for themselves, by their own proper weight, irregular fistular cavities. It appears as if a small quantity of resin first collects, and having formed a cyst, attracts more of the same substance to itself; and then acquiring volume and weight,

settles down among the cells or tubes, forming what are called turpentine vessels.—(*See* page 71.)

Volatile oils are found nowhere but in the leaves, flowers, or bark of plants, where, like resins, they form little cysts for themselves. Occasionally they are present in the pericarp or the seed, as in Anise and Coriander in the former case, and in the Nutmeg in the latter. They are said to be composed of two distinct principles—*elæadine*, or the volatile, and *stearoptine*, or the concrete portion. These two are usually intimately combined in nature, so that they can only be separated by artificial means; but De Candolle thinks that, in the case of Camphor, we have the stearoptine in a separate state in nature. This substance is of by no means uncommon occurrence. Combined with a volatile oil it exists in Rosemary and Marjoram to the amount of 10 per cent., and in Lavender of 25 per cent; but in a naturally concrete state it occurs only in certain Laurels, such as the Laurus camphora and Sumatrensis; and in a large tree of the Malayan Archipelago, called Dryobalanops camphora, in whose bark, roots, and wood it is secreted in tears varying in size from a pea to that of a grain of sand.

Fixed oils have neither special forms of tissue nor irregular cavities within which they are deposited; but, like starch, they occupy and fill the interior of common cells. It is neither in the leafy nor cortical organs that they occur, but chiefly in the seed, as in the Flax; or occasionally in the pericarp, as in the Olive. They are more especially common in albumen, as in Palma Christi; and may probably be considered as a secretion which concurs, in some unknown manner, to the nutrition of the embryo plant. As there is scarcely any vegetable product more extensively useful than fixed oil, nor one which is more generally sought for mercantile purposes, it will not be without interest to know in what proportions it has been found to exist in the various seeds from which it has been pressed for profit. For this reason we borrow the following table from De Candolle:—

Seeds of the	Per cent. in weight.
Hazel Nut	60
Garden Cress	56 to 58
Olive	50
Walnut	50
Poppy	47 to 50
Almond	46
Common Spurge (Euphorbia lathyris)	41
Colza Rape	39
White Mustard	36
Tobacco	32 to 36
Plum	33
Common Rape	33
Summer Rape	30
Woad	30
Gold of Pleasure	28
Hemp	25
Fir	24
Flax	22
Black Mustard	18
Sunflower	15
Buck-wheat	12 to 16
Grape	10 to 18

§ 3.—*Local Secretions.*

Besides the two foregoing classes of secretions, there is a very considerable number which never enter into the general system of vegetation, and which have no particular situation, being found indifferently in many different parts of a plant. Many of them are very imperfectly known: they have nothing to do with the functions of vegetation, so far as we know; and it will be quite sufficient if we enumerate them in lists, under the heads of Acids, Alkalies, Neuter, Resinous, Tanning, and Colouring Principles.

Acids.—1. Ulmine, Ulmic, or Humic, which is also considered, with great probability, as being nothing more than the carbonaceous remains of dead vegetable matter; 2. Gallic; 3. Acetic, or Pyroligneous; 4. Malic; 5. Citric; 6. Pectic; 7. Rheic; 8. Krameric, 9. Ginkoic; 10. Glamic; 11. Lichenic; 12. Selenic; 13. Oxalic; 14. Tartaric; 15. Equisetic; 16. Moric; 17. Kinic; 18. Meconic; 19. Igasuric; 20. Abietic; 21. Pinic; 22. Sylvic; 23. Benzoic; 24. Kahinsic; 25. Phocenic; 26. Stearic; 27. Hydrocyanic, or Prussic; 28. Aspartic; and 29. Fungic.

Alkalies.—1. Delphine; 2. Aconitine; 3. Picrotoxine; 4. Morphine; 5. Sanguinarine; 6. Corydaline; 7. Violine; 8. Esculine; 9. Guaranine; 10. Brucine; 11. Coneine; 12. Quinine; 13. Cinchonine; 14. Strychnine; 15. Strychnochromine; 16. Solanine; 17. Nicotine; 18. Atropine; 19. Hyoscia-mine; 20. Daturine; 21. Daphnine; 22. Rhabarbarine; 23. Buxine; 24. Veratrine; 25. Smilacine.

Neuter Principles.—1. Gluten;

2. Vegetable Albumen, or Glutine; 3. Pollenine; 4. Berberine; 5. Asparagine; 6. Amygdaline; 7. Emetine; 8. Coffeine; 9. Narcotine; 10. Gentianine; 11. Plumbagine; 12. Amanitine; 13. Fungine; 14. Osmazome; 15. Adipocire; 16. Gelatine; 17. Fibrine.

Resinous Principles.—1. Polygaline; 2. Hesperidine; 3. Aurade; 4. Zanthopicrite; 5. Busurine; 6. Quassine; 7. Cathartine, 8. Coumarine; 9. Glycyrrhizine; 10. Caryophylline; 11. Coloquintine; 12. Elaterine; 13. Olivine; 14. Jalapine; 15. Digitaline; 16. Laurine; 17. Piperine; 18. Salicine; 19. Populine; 20. Corticine; 21. Abietine; 22. Scillitine; 23. Zeine.

Tanning Principle.—Tannin.

Colouring Principles.—1. Hematine; 2. Breziline; 3. Santaline; 4. Morin; 5. Fustel; 6. Quercitrine; 7. Orcanettine; 8. Alizarine; 9. Purpurine; 10. Xanthine; 11. Dragon's Blood; 12. Curcumine; 13. Luteoline; 14. Indigotine; 15. Pittacul; 16. Chromule; 17. Carthamine; 18. Polychroite; 19. Rheadine; 20. Varioline; 21. Orcine.

Chapter X.

Of Vegetable Excretions.

All the secretions hitherto spoken of are found in the inside of plants, and may be supposed to be innocuous, at least, if not useful, in the process of vegetation, as no attempt is ever made by plants to rid themselves of them, unless by accident.

There is another class, consisting of matters of various kinds, which would seem to be incompatible with the healthy being of vegetation, as we find them constantly thrown off on the outside of the root, or the stem and leaves, sometimes in the form of solid concretions, sometimes as viscid, or glairy, or other discharges, or most frequently as volatile emanations, which cause the various odours of the vegetable kingdom. These may be considered analogous to those parts of the food of animals which are voided, after having been deprived of their nutritious principles, and are therefore called excretions. We shall pass these rapidly in review, dwelling principally upon those of the roots, which seem to be the most important to man.

§ 1.—*From the Stem or Leaves.*

There is a plant common in gardens, called Fraxinella, whose leaves and stem are covered with little brown resinous glands, emitting a powerful balsamic odour. This plant, in warm weather, is surrounded by an inflammable atmosphere, formed by its own vapour, which will take fire when a light is applied to it, and produce a bright, rapid flame, which does no injury to the plant. It has been ascertained that this vapour is not hydrogen, but a volatile oil suspended in the atmosphere. Chenopodium vulvaria and several fragrant flowers have been found to give off pure ammoniac, and maritime plants are said to exhale chlorine.

Acid excretions are formed by the hairs of the Chick Pea, the Stagshorn Sumach, and some other species; and it is supposed that the singular property possessed by certain Lichens of immersing themselves in the calcareous rocks they inhabit, is owing to their excretion of oxalic acid.

The stinging power of the Nettle and similar plants is produced by an acrid matter which their hairs have the power of emitting when pressed, and which varies in intensity in different species. The Nettles of Europe simply produce an uneasy sensation, but some of those of India have brought on lock-jaw, and even death itself in torments; for the effect of their sting is represented to resemble boiling oil flowing over the part affected.

A discharge of *sticky* matter by the hairs, or simply by the surface, is of very common occurrence, especially by the former, which will be seen with minute drops of the excretion hanging from their points. It is this which gives their viscidity to such plants as the Rose Acacia, to the buds of the Horsechestnut, and the Tacamahac Poplar, and to the young leaves of the Birch tree. It is said to be in many cases chemically analogous to Birdlime.

Wax, or substances analogous to that production, and so called, is, in one shape or another, of very common occurrence on the surface of plants, and it exists even in their substance, as in pollen, some barks, &c. It forms the bloom of such fruit as the Plum and the Cucumber; it causes the glaucous appearance of Cabbages and Seakail, and produces the powdery efflorescence that is found on the surface of many Chenopodeous plants: in these cases it constitutes a coating which repels

water, so as to protect the parts from which it is excreted from the effect of humidity. In some instances wax is thrown off by plants in such considerable quantity, as to render the collection of it an object of trade. The Candleberry Myrtle (Myrica cerifera) has its berries guarded by a thick coat of vegetable wax; if thrown into boiling water, the wax is melted and floats, when it is skimmed off, and converted into candles of good quality; they are, however, green. The berries of this plant have been stated to furnish about one-ninth of their weight of wax. The Wax Palm (Ceroxylon Andicola) has its trunk covered with a thick coating of wax, which seems to ooze out from all parts of the surface both of the bark and leaves.

Sugar, or at least saccharine matter in a liquid state, is too well known in the form of the honey of flowers to require more than to be pointed out; in a solid form it is less common. We have it however in a crystalline state, secreted by the upper lip of the flowers of the Rhododendron Ponticum, and in the beak of Strelitzia; it exists upon the surface of a kind of Sea-weed called Fucus saccharinus, and it appears in large solid concretions as Manna. This substance, which is discharged in Europe chiefly by the Flowering Ash (Fraxinus ornus), either in consequence of wounds artificially inflicted on the branches, or of the punctures of insects, is produced by other plants in other countries. The Manna of Scripture is yielded by a species of Tamarisk, and by the Camel's-thorn (Alhagi Maurorum); it distils in India from a kind of Celastrus, and the common Larch furnishes a particular kind of Manna in no inconsiderable quantity.

In addition to the foregoing instances of excretions from the leaves or stems or flowers, there remains to be noticed the saline efflorescence of marine plants; a glairy substance which clothes the surface of submersed plants apparently for the purpose of protecting them from immediate contact with so active a solvent as water; discharges of insipid fluid from the points of the leaves of certain plants, especially of the Cæsalpinia pluviosa, a Brazilian tree which is said to produce a shower of drops of water resembling rain, and finally the pulpy matter which occurs in the inside of the seed-vessels of many fruits: the last-mentioned substance is an austere and acid fluid in Sophora Japonica; an opaque sub-acid pulp in the Tamarind, and an odoriferous stimulating juice in the Balsam of Tolu plant (Myrospermum toluiferum); in Cathartocarpus fistula it is a viscid purgative extract; in the Arnotta fruit it is a coloured powdery matter; in the common Quince it is a mucilaginous secretion, which covers the seeds; and there is a great many other kinds.

§ 2.—*From the Roots.*

That roots give off in some cases a peculiar matter, has been known for some time. Brugmans was the first to observe it in the Heartsease, and it was afterwards remarked in the Elm and some other plants. No one, however, seems to have suspected this to be a general function of vegetation before M. De Candolle, who as long ago as the year 1805 called attention to this curious subject. It now appears from experiments conducted by M. Macaire of Geneva, that to throw off excretions by the roots is a general property of plants, and one of their most important vital actions; that the matter so thrown off is in most cases deleterious to the species ejecting it, although it may be harmless to others, and that particular species discharge by their roots a matter so deleterious as actually to poison the soil. He found that Leguminous plants produce a substance analogous to gum, and a little carbonate of lime; grasses a minute quantity of matter containing certain alkaline and earthy muriates and carbonates, but very little gum; that Chicoraceous plants exude in abundance a brownish bitter excretion analogous to opium, and containing tannin, a gummy extractive brown matter, and certain salts; Papaveraceous plants a substance of a similar nature; Euphorbias a gummy resinous secretion of a yellowish white colour, and of an acrid flavour, and so on.

This fact probably explains why a plant will not generally succeed if planted in the earth which has been previously occupied by the same species. An apple-tree will not grow on the spot where an apple-tree has previously grown; wheat will not follow wheat, nor an oak-tree an oak; and this not from the soil being exhausted of nutritive principles, for the same effect will take place whatever the quantity of manure that is employed. This cir-

cumstance had always been inexplicable till the discovery of secretions from roots; for the old supposition that each plant was able to select its peculiar food from the soil, and so to exhaust it for itself, although not for others, was perfectly gratuitous. It now appears that, as roots absorb indifferently everything sufficiently fluid which is presented to them, when one species immediately follows another in the same soil, it is placed in the same situation as an animal compelled to feed upon its own excrement; and we know from experiment that they cannot bear that. For if you place a plant of Belladonna in a weak solution of extract of Belladonna, it is rapidly killed. The faculty indeed which plants possess of getting rid of the excretions of the roots would seem to be a necessary condition of their life; for if they had not such a power, the fæcal matter which they now part with would be redissolved by the ascending sap, and carried back into their system to their own destruction. Macaire showed by a simple experiment that a plant, if poisoned, will disembarrass itself of the offending matter by its roots if it has the opportunity. He took a plant of Mercury (Mercurialis annua), and divided its roots into two parcels, one of which he introduced into a weak solution of acetate of lead, and the other parcel into pure water; at the end of a few hours the water which was originally pure had become perceptibly impregnated with acetate of lead, which had therefore been taken into the circulation by the roots on one side of the plant, and thrown off again by the roots on the other.

Until a greater variety of experiments shall have been tried upon the nature and mutual action of excretions of this nature, it will be impossible to determine to what extent the discovery is of practical application. In the mean while it remains highly probable that it explains the cause of certain plants being considered weeds, or, as the French say, *mauvaises herbes*, that is, injurious to their neighbours; and that it will enable the scientific agriculturist to reduce to some intelligible laws the practice of farmers in regard to the succession of their crops, which is as yet entirely empirical. It moreover appears certain that it explains the cause of plants grown in pots, notwithstanding the quantity of manure that is given them, becoming unhealthy, unless their soil be frequently changed.

Chapter XI.

Flowering.

The foregoing Chapters will have explained by what means plants are nourished, and what the general result is of their nutritive action. The phenomena attendant upon flowering and fruiting have next to be considered.

The act of flowering or of expanding the flower is that which appears the most striking to ordinary observers, but it is in reality a mere preparation for the far more important act of reproduction. A great many highly-curious and interesting facts have been collected concerning it, but they are so little understood, their mutual connexion is so little apparent, and we are so far from comprehending their value in relation to other functions, that we shall occupy but little space in this treatise with their explanation.

Flowers are always prepared in the centre of the buds, or embosomed among the leaves for a considerable time before they expand. It is probable that the causes which conduce to dispose their parts to become sepals, petals, &c. instead of leaves, take effect at a very early period, when they are extremely rudimentary; but what the exact nature of those causes is we do not know. In general they are formed so rapidly, that a few months are sufficient to pass them through their larvæ state, but in certain Palms some years appear to be required. It is said that the rudiments of flowers may be discovered in the central bud of these plants as much, in some instances, as seven years before the perfect flowers expand. To watch the gradual change of the organs in such cases as these would be at once one of the most instructive and amusing inquiries in which a Botanist with leisure, opportunity, and good faith, could engage.

To what causes the production of flowers is owing is uncertain; it must generally be referred to the specific nature of plants, or what is called their idiosyncracy. Annuals, for instance, flower in a few weeks after their seeds are sown; what are called biennials demand some months; perennials a longer time, and trees several years: we know no more of the cause of this,

than of the cause of their being annuals, biennials, perennials, and trees. Some, again, blossom in the winter, as the Chimonanthus, the Christmas Rose, and the fragrant Coltsfoot; others in the earliest spring, as the Snowdrop, Adoxa, and the Crocus; while others, like certain species of Michaelmas Daisy, and the Chinese Chrysanthemum, cannot be made, by any known artificial means, to advance their autumn flowering even a few weeks. Plants, in short, have a periodicity of flowering varying in different species, which appears inherent in their own proper nature, and not capable of explanation upon any hypothesis worth mentioning.

The same is true of the hours at which they open their blossoms; one expands at dawn of day, another species a few hours later, a third at mid-day, some in the early evening, and a few when darkness has established her dominion. Hence, what are called the *Watches of Flora* have been constructed; tables in which every hour of the day is filled up by the expansion of some flower; but however useful these may be for comparing climate, they assuredly conduce in no degree whatever to elucidating the causes of the singular phenomena they represent.

Certain facts there are, however, which are deserving of notice, because they have a general application, and serve to throw light upon some of these obscure and unintelligible phenomena.

It would seem to be a general law that the quantity of flowers which a plant produces will be in proportion to the quantity of nutritious matter which that plant may be able to accumulate. If a Hyacinth is deprived of its leaves one year, it will not blossom the succeeding year; but if its leaves are so fully exposed to light and air that they go through their growth in uninterrupted health, and the flowers are destroyed for one year, the bulbs will blossom more finely than ever the succeeding year in consequence of the great quantity of nutritious matter that will have accumulated; for, in this case, not only is a sufficient quantity secreted by the leaves, but the stock prepared the previous year remains unexhausted in consequence of the flowers, which would have consumed it, having been destroyed. After hot and bright summers, when leaves have been in uninterrupted action, and a great quantity of solid matter has been deposited, as is obvious in the stunted state of the branches, a most abundant crop of blossoms is invariably the result; while the reverse takes place after cold and gloomy summers, which produce weak and watery shoots. Or if a tree is sterile, its branches may be made fertile by depriving them of a ring of bark near their insertion; this interrupts the backward flow of the sap, causes the nutritious secretions to collect above the annular incision, and thus brings on the formation of flowers. It is not improbable that this may be explained upon the supposition that when plants are in a state of slow growth, as in hot and dry summers, the appendages of the axis are retarded in their growth, fixed in whorls, and receive a tendency to imperfect development which will inevitably produce flowers; while, on the contrary, no arrestation of growth, nor any fixing in whorls, will take place when plants are in a state of constant and rapid growth, and consequently nothing but leaves will be the result. This will be the better understood by a reference to the laws of Morphology (Chap. XXV., Part I.); and is, to a certain extent, illustrated by a fact well known to all observing gardeners, that, in wet and warm springs, a great number of the blossom buds of Pears and Apples are converted into leaf-buds by the excessively rapid development which they undergo breaking up the whorls of their flowers, throwing an excessive quantity of sap into the organs which had been destined for flowering purposes, and thus converting them into leaves.

There is also another fact which seems to show that flowering depends upon the accumulation of a sufficient quantity of nutritive matter in the part which is to flower. An Apple when raised from seed, and left to unassisted Nature, will not flower in less than on an average seven years. But if a cutting of it, one year old, be grafted upon an old bearing tree, which is able to infuse into it a large quantity of nutritive matter, it will bear the second year after being grafted; so that by this means in three years at the latest a plant may be artificially made to bear, which, under ordinary circumstances, would not flower in less than seven at the soonest.

The mere act of flowering is a pre-

paration for fertilization, with reference to which it is principally important, and in relation to which some other circumstances will be spoken of. As soon as fertilization is accomplished, a new being, the embryo, is called into existence, which attracts to itself all the nutritive matter that was before conducted to the sepals, petals, and stamens; the latter then shrivel up, and the act of flowering is accomplished. There are, however, some curious exceptions to this rule. In many plants the sepals continue to grow after fertilization has taken place. In others, as the Burmese Varnish Tree (Melanorrhœa) the petals become excessively enlarged; but the stamens uniformly perish.

For the amusement of those who are interested in such matters, we subjoin a *Watch of Flora*,—that is, the hour of expansion of various flowers, as it is recorded by Linnæus for Upsal, and by De Candolle for Paris:—

Name of Plant.	Upsal.	Paris.
Convolvulus nil and sepium	..	3–4 a.m.
Tragopogon pratense . .	3–5 a.m.	4–5 a.m.
Other Cichoraceous plants	4–5 do.	do.
Matricaria suaveolens. .	...	do.
Crepis tectorum . . .	4–5 a.m.	...
Papaver nudicaule . .	5 a.m.	5 a.m.
Moist Cichoraceæ . .	...	do.
Momordica elaterium . .	...	5–6 a.m.
Lapsana communis, and many Cichoraceous plants	5–6 a.m.	do.
Convolvulus tricolor . .	...	do.
Hypochæris maculata .	6 a.m.	6 a.m.
Solanum, several species	...	do.
Convolvulus Siculus . .	...	do.
Sonchus, different species	6–7 a.m.	6–7 a.m.
Hieracium, do.	6–7 a.m.	do.
Nuphar and Nymphæa .	7	7 a.m.
Lactuca sativa . . .	...	do.
Camelina sativa . . .	...	do.
Prenanthes muralis . .	...	do.
Mesembryanthemum barbatum	...	7–8 a.m.
Specularia speculum . .	...	do.
Cucumis anguria . .	...	do.
Calendula pluvialis . .	7 a.m.	do.
Anagallis arvenesis . .	8	8 a.m.
Dianthus prolifer . .	8	...
Nolana prostrata . . .	...	8–9
Hieracium chondrilloides	9	..
Calendula arvensis . .	9	...
Mesembryanthemum barbatum, &c.	7–8	...
Mesembryanthemum crystallinum	9–10	9–10
Arenaria	9–10	...
Mesembryanthemum nodiflorum	10–11	10–11
Portulaca sativa . . .	...	11
Ornithogalum umbellatum (called on that account Dame d'onze heures)	..	11
Tigridia pavonia . . .	...	do.
Most Ficoideous plants .	...	12
Scilla pomeridiana . .	...	2 p.m.
Silene noctiflora . . .	9–10	5–6
Mirabilis jalapa . . .	5	6–7
Pelargonium triste . .	6	...
Cereus grandiflorus . .	9–10	7–8
Mesembryanthemum nocti-florum	...	do.
Œnothera tetraptera . .	...	do.
——— suaveolens . .	...	do.
Convolvulus purpureus .	...	10 p.m.

Chapter XII.

Fertilization.

Upon looking to the writings of ancient authors, we find that, from a very early period, the world was acquainted with two cases in which the presence of flowers of a particular kind was necessary to ensure the fertilization of another kind borne by the same species, ultimately bearing fruit if fertilization was effected; but remaining sterile provided the flowers of the first kind were not permitted to exercise their influence. One of these cases was the Date Palm, the other was the Fig.

Man had learned from experience that those flowers of the Date, in which the beginning of a fruit was discoverable, would never arrive at maturity unless sprinkled with the powder secreted in the flowers of other individuals of the same species of Palm: and hence they considered the latter to be males and the former females; which was true. Wild Figs again were found to be necessary, by coming in contact with it, to enable the fruit of the cultivated Fig to mature; and hence they also supposed the former to be males and the latter to be females, which, however, was *not* true. Caprification, as this latter phenomenon was termed, did not depend upon the powder of the wild Fig coming in contact with the young fruit of the cultivated Fig, but upon a totally different circumstance; for both kinds of Fig are in reality perfect in themselves. What makes the act of caprification necessary is this,—that the flowers of a Fig are inclosed in a fleshy case, which finally becomes the fruit, and, from some unknown cause, does not readily ripen unless injured by the puncture of an insect.

The Wild Fig abounds in a little fly called a Cynips; and, consequently, when the former is brought into the vicinity of the cultivated Fig, the latter is attacked by the Cynips, and so enabled to mature. It is clear from their having confounded, under the same idea, two phenomena so essentially different as these, that the ancients had no real knowledge of the sexes of plants; and it is probable that all their notions were deduced from hypothetical considerations arising out of the comparison drawn by their philosophers between plants and animals, than from any exact knowledge which they possessed.

Nor, indeed, is there any reason to believe that the discovery of the sexes in plants, as a general fact, can be traced farther back than the time of Sir Thos. Millington, Green, Malpighi, and Ray. The latter said in express terms, in the year 1694, that the points of the stamen are the most essential parts of a flower, as they contain pollen, which, in his opinion, is endowed with a prolific power, and serves to fertilize the seeds. From this time the question was settled among botanists, notwithstanding the captious objections of a few writers whose names and opinions have alike sunk in oblivion. It was Linnæus, however, who brought the subject more particularly before the world, in consequence of his having employed the sexes of plants as the basis of his classification; and although, in point of fact, this writer added little or nothing to what was before known, and even by his speculations upon hybrid plants rather tended to weaken the theory in the eyes of men of science, yet the attractions of his style, and the skill with which he embellished the subject, were such, that the vulgar believe him to have been the discoverer of the existence of vegetable sexuality. From his time to the present every succeeding observation has tended to confirm this curious fact; and the mass of evidence is now so great, that no one thinks of calling its truth in question as a general law of Nature.

In fact, if the thing is considered a little, we find on all sides the clearest evidence that seeds cannot be fertilized without the contact of pollen and stigma. We select a few of the most striking. Maize is a kind of corn, the anthers of which are formed in the loose panicles that terminate the stem; the styles, with their stigmas, are the long silken tassels which hang down from the short branches near the base of the stem. If the panicles are destroyed, the stigmas are not fertilized, and no grain is produced. Take an Apple-blossom, and cut out the anthers before the anthers burst; no apple will be formed. Let the stamens be all converted into petals, as in double flowers, and the pistils are barren, however perfect they themselves may be. In a Cucumber plant some of the flowers bear nothing but stamens, and others contain nothing but pistils. If the former are carefully cut away, the latter, instead of swelling immediately after the flower has withered, will become yellow, cease growing, and suddenly drop off. We are therefore sur rounded by proofs of the necessity of the anthers to fertilize the pistils.

Nevertheless, as in some animals, so in some plants, it appears that parts analogous to flowers produce fertile bodies, resembling seeds in their power of reproducing the species, without there being any trace of anthers. This occurs in Ferns, Fungi, Lichens, Seaweeds, and, in all probability, in every tribe of flowerless plants. This fact has led some botanists to deny the necessity of anthers in species where they are regularly produced. It has been asserted that the Basil (Ocymum), Hemp, and Spinach will produce fertile seeds without coming in contact with the pollen; but while this is asserted by one observer it is denied by another, and appears altogether so contrary to common sense as to be undeserving any further remark than this, —that in those species anthers are regularly produced, as perfect in their structure as in any plants whatever; and that it is not probable they would be so produced unless they had their usual office to perform. Are we to believe that no sexes exist in the animal kingdom because the Aphis is increased without their aid? Passing by, then, these speculations, let us look at the highly-curious phenomena of fertilization, as understood by the best observers.

When the flower unfolds, the anther is a tolerably solid, moist body, filled with moist pollen. The grains of the latter contain a fluid more dense than the tissue that forms a covering for them, and rapidly absorb its moisture from the anther case. As soon as this

has happened to any great extent, the tissue of the anther case contracts, and at first rends into grated cells of various forms; as the dryness is increased, these latter contract still further, and exercising a general power over the whole surface of the lining, would, in the end, be rent into still finer portions, if it were not for the slight degree of cohesion which exists between the valves of the anther at the sutural line. Here, then, the lateral strain of the contracting cells compels the anther to open, and the pollen is enabled to fall out.

At the same time that this is going on in the anther, the tissue of the stigma is becoming more and more lax, and secreting a viscid fluid between its cells; so that by the time the pollen is discharged from the anther, the stigma has become an uneven, clammy surface, with prominent cells, between which any foreign matter can be easily insinuated.

Upon the stigma thus prepared the grains of pollen either drop or are cast, or are conveyed by wind, insects, or other means; and there they are secured by the clamminess of the organ.

When the grains of pollen have lain upon the stigma for several hours they open at their angles, or upon certain definite points of their surface, and the thin inner lining, which is of a highly-extensible nature, is gradually prolonged into extremely slender intestines, called *pollen-tubes*, which sink into the tissue of the stigma, burying themselves within it, just as the roots of a plant bury themselves in the soil.

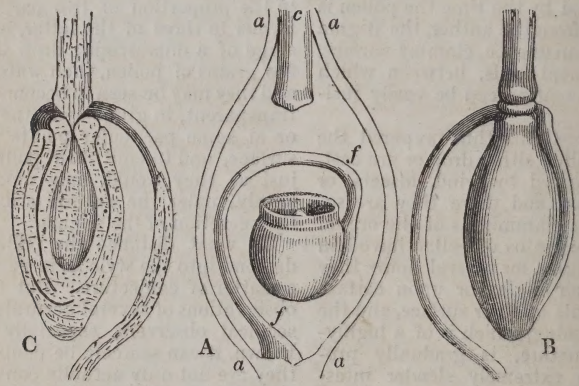
By means of the pollen-tubes the matter contained in the pollen-grains is conveyed into the interior of the style, whence it is supposed to pass into the ovule. This matter has been already (p. 42) described as consisting of round and oblong minute particles floating in liquid; and it is believed that the fertilizing principle, be it what it may, resides in those particles,—perhaps only in the larger kind, perhaps in the smaller—possibly in both. In general, it is very difficult to see the pollen-tubes; for if the pollen rubs freely from the surface of the stigma, the tubes are not emitted; if it is removed with difficulty, the tubes are broken off. They may, however, be easily seen in any Gesnera, by scraping from off the stigma pollen that has been in contact with it at least forty-eight hours. The Crocus also parts with its pollen-tubes easily; and if a minute portion of the stigma of Crocus vernus is pressed gently in water between two plates of glass till it is transparent, the pollen-tubes will be distinctly seen buried in the stigma, with the turbid matter of the pollen lying in unequal quantities in their inside. Amici recommends the Althæa frutex for the same observation; but that plant is not well adapted for examination, because in this northern climate its pollen is rarely perfect. Should a difficulty be after all experienced in witnessing these singular phenomena, it may be brought about artificially by the following simple means. Place a drop of a solution of concentrated sulphuric acid and water, in the proportion of two parts of the former to three of the latter, upon the stage of a microscope; drop into it a few grains of pollen, then watch them, and they may be seen to become rapidly transparent, to give way at the angles, or at some particular points of their surface, and to emit their pollen-tubes just as they would, only much more slowly, under the natural stimulus of the secretion of the stigma.

To what distance the pollen-tubes descend into the style is, in most cases, a matter of conjecture. But from the observations of several accurate microscopical observers, especially of Dr. Brown, it can scarcely be doubted that they are not only actually conveyed to the placenta, but are introduced into the ovules. This distinguished Botanist confirms the statement of Du Petit Thouars, that a cord developed in the stigma of Orchideous plants may be traced to the placentæ and consequently to the ovules; and he declares that this cord is entirely composed of pollen-tubes. He found the branches of the cord scattered over the whole surface of the placentæ in Orchis Morio; and he even succeeded in tracing in several, though not in many instances, a single tube to the foramen of an ovule. He was also so fortunate as to witness the same phenomenon in many cases in Habenaria viridis. Adolphe Brongniart also describes the pollen-tubes in the Rock Rose (Helianthemum) as entering the cavity of the ovary, and descending from its summit till they reach the ovules.

In connexion with these phenomena, there is another class of actions on the part of the ovules which it is important to be aware of. In many cases it has

been seen, and it is probable that in all cases it happens that at the time when pollen-tubes are plunged into the stigma, the ovules adjust themselves so as to present their foramen either to the placenta, or else to that point of the lining of the ovary by which the pollen-tubes afterwards enter. This is plainly the case in the Rock Roses just referred to; in Euphorbias it may also be witnessed; and the very act of curving which takes place in so many ovules, as has already been mentioned (p. 46, *fig.* 61), is no doubt for the purpose of effecting the same object. If we examine the ovule of the Spurge Laurel (Daphne Laureola), before the pollen falls upon the stigma, we shall find its foramen turned towards the dome of the ovary, but far from touching it. Soon after the pollen has acted upon the stigma the ovule approaches the dome, a short process in direct communication with the stigma is at the same time protruded from the dome, and finally closes up the foramen, thus bringing the nucleus of the ovule in direct organic communication with the stigma. A similar case of rather a more complicated kind, and not so easily witnessed as the last, occurs in the Thrift plant (Armeria vulgaris), *fig.* 100.

Fig. 100.



Let the ellipse *a a*, *fig.* A, represent a section of the ovary of this plant. From its base there arises an umbilical cord *f f*, which curves after reaching about half the length of the cavity, and bending down upon itself again turns partially up, bearing an ovule at its apex. When very young this ovule is a sort of cup, the mouth of which is closed by a little cone, and is turned towards the apex of the ovary. From all access to the dome of the ovary the ovule is cut off, notwithstanding its position, by the cord which over against the aperture of the ovule spreads into a kind of strap. It is from the point of the ovary *c*, that the stigmas arise; and from immediately below their origin a short cylinder projects down into the cavity of the ovary. Matters being thus arranged, the pollen falls upon the stigma, and pollen tubes are forced into its tissue and gradually find their way into the cylinder; at the same time the ovule lengthens, contracts at its aperture, and is brought near the cylinder by the elevation of its umbilical cord; at last the strap is slipped aside, the cylinder lengthens, the ovule rises, and with its aperture embraces the point of the cylinder, which is somewhat conical, and which is thus brought into contact with the nucleus. At this time the parts are in the position represented at *fig.* B; and if cut through longitudinally, as at C, they will be seen to be placed in the most favourable position that can be imagined for enabling any fertilizing matter that may have been communicated to the stigma to find its way into the interior of the ovule.

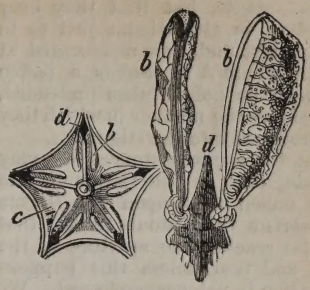
What the nature is of the communication thus made by the pollen to the ovule through the medium of the pollen-tubes, the result of which is fertilization, we have no means of knowing. It may either be a peculiar stimulus which is required to call into existence an embryo germ of life residing in the point of the nucleus; or it may be the act of conveying such a germ to the

nucleus from out of the pollen grains. Opinions are divided upon these points, and they are likely to remain so; for we can conceive no means of solving the problem. It may, however, be remarked, that Dr. Brown declares that he could not discover the pollen-tubes of Orchideæ, even in their earliest stage, while in length hardly equal to the diameter of the grain, to contain distinct granules; and that when, with a magnifying power of 300 or 400, minute and very transparent granular matter came into view, it was extremely different from the granules of the pollen-grains. As it is not improbable that this may be a special and not a general case, and that it is connected with the peculiar structure of Orchideous plants, we do not think much stress ought to be laid upon it in the present state of our knowledge; especially as pollen-tubes do, in other instances, most unquestionably contain the molecular matter of the pollen-grain, whatever the functions of that matter may be considered to be.

The principal difficulties in the way of admitting actual contact between the pollen and the stigma to be indispensable to fertilization, exist in Orchideous and Asclepiadeous plants; in both which Nature seems to have taken infinite pains to prevent such contact. In the former, in particular, there are many cases in which actual contact seems physically impossible, and there are others in which it is very improbable; and although the pollen when placed upon the stigma is undoubtedly capable of producing its tubes, yet as molecular matter cannot be detected in them, it may be doubtful whether the pollen-tubes when developed are not rudimentary organs. Several botanists, and particularly Mr. Bauer, believe that fertilization takes place in these plants by some peculiar mode of internal communication; but whatever may be the fact with regard to Orchideous plants, none can now remain in regard to Asclepiadeous plants, after the luminous explanations of the manner in which it is effected which have appeared within these few years, especially from Ehrenberg, Brown, and Adolphe Brongniart.

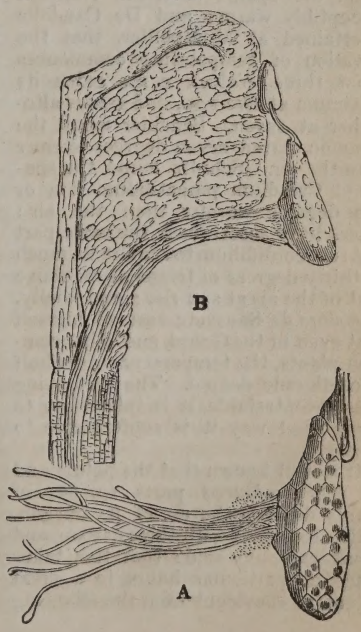
In these plants the stigma is a fleshy five-cornered disk, having a gland (*fig.* 101, *d*) at each angle. To each gland is attached a pair of yellow bags (*b*) containing the pollen, and called *pollen*

Fig. 101



masses; which are more convex on one edge than on the other. The stigma itself has no visible secreting surface; and as the pollen masses had never been seen to discharge the pollen grains, it was supposed that fertilization must be in this case effected by some internal communication through the glands. But Ehrenberg proved that the grains of pollen produce pollen-tubes all directed towards the most convex edge of the pollen mass, which is also the thinnest, and that they are eventually forced through it. Brown and Brongniart, pursuing this fact, instituted some very careful observations upon the sub-

Fig. 102.



ject, the result of which proved not only that pollen tubes are emitted by Asclepiadeous plants, but that they bury themselves in the stigma just as in other plants, and as is represented at *fig.* 102, where A represents a pollen mass with its pollen-tubes protruded, and B shows the manner in which they are introduced into the stigma.

From these circumstances we may conclude, that in the fertilization of plants pollen falls upon the stigma and inserts a tube into its tissue; that the tube reaches the aperture of the ovule; and that unless this happens fertilization is not accomplished. We must here dismiss this curious subject, leaving many most interesting facts untold, and proceed at once to other matter.

Chapter XIII.

Of the Temperature of Flowers.

If we test the temperature of a flower, however large it may be, it is extremely probable that we shall discover no difference whatever between it and the external air. And yet it appears certain from well-attested observations, and probably from theory, that flowers have at certain periods of the day a temperature much elevated above that of the air which surrounds them. Lamarck found the spadix of Arum Italicum perceptibly warm; and De Candolle ascertained at Montpellier, that the elevation of temperature commences about three o'clock P. M., gains its maximum at five P.M., and ceases altogether at seven. Senebier found the common Arum seven degrees warmer than the air. Schultz found the spadix of Caladium pinnatifidum four or five degrees warmer than the air; others have ascertained the same part in Arum cordifolium to acquire as much as thirty degrees of temperature above that of the air at sun-rise; and finally, Theodore de Saussure assured himself that even in the Gourd, and other common plants, the temperature rises half a centigrade degree. The fact being thus incontestable, it is interesting to see in what way it is conformable to theory.

It is well known that the petals and all other *coloured* parts (p. 90) of plants deprive the air of its oxygen, which combines with their carbon and forms carbonic acid: that this takes place at particular hours to a great extent, as is evident from the following table of the result of some experiments made by Theodore de Saussure upon the proportion of oxygen consumed by plants in proportion to their volume, when placed in receivers of atmospheric air over mercury; the experiment lasting twenty-four hours, and the external temperature being between 18° and 25° centigrade.

	Oxygen consumed by Flowers.	Leaves.
Common Stock, single red var.	11	4
Ditto, double	7·7	
Tuberose, single	9	3
Ditto, double	7·4	
Brugmansia arborea	9	5
Passiflora serratifolia	18·5	5·25
Hibiscus speciosus	8·7	5·1
Gourd, sterile Flowers	12	6·7
White Lily	5	2·5
Typha	9·8	4·25

&c. &c. &c.

It was also ascertained that the stamens and pistils are still more rapacious of oxygen. Those of the Stock consumed 18 times their volume instead of 11½; of the Nasturtium, 16·3 instead of 8·5; and of the Gourd, 16 instead of 7·6. But it was found that this takes place to the most considerable extent in Arums. While the spathe of the common Arum consumed only 5 times its volume of oxygen, its spadix destroyed 30 times, and that part on which the stamens and pistils are placed as much as 32 times.

Hence it would seem that the high temperature of flowers is owing to the combination of oxygen and carbon, which produces a kind of combustion; and if so, we ought to find signs of disengagement of caloric by all flowers. It is, however, to be remembered, that in by far the greater number of flowers the heat is carried off by the atmosphere the instant it is disengaged, and that it is only where flowers are collected in great numbers within cases which act as non-conductors and confine the heat, as happens in Arums, that the elevation of temperature becomes appreciable.

Chapter XIV

Of Fruiting.

Immediately after fertilization has taken place, all the parts of the ovary swell, the ovule closes its aperture, the stigma loses its humidity, the vessels of the style collapse, and the latter organ either drops off or hardens upon

the ovary as a rigid process; while at the same time an embryo plant developes in the inside of the ovule. This latter occurrence never supervenes unless the act of fertilization is accomplished; all the others may take place, the ovary may grow, and even the integuments may acquire their mature dimensions, in the absence of it.

In by far the greater number of cases, the pericarp becomes more and more leathery, woody, cartilaginous, or membranous, and gradually changes from green to brown or white; and in such cases the world is scarcely conscious of the production of fruit. But in some instances the pericarp acquires a greater volume, becomes succulent instead of drying up, often acquires the gayest colours, and in time becomes what we popularly term fruit, that is, a body which may be eaten, or looks as if it might. It is said that, in the former of these cases, the surface of the fruit abounds in stomates, which enable the fluid matter of the pericarp to be freely evaporated, and that in the latter an absence of stomates causes the fluid matter to accumulate; but it is to be suspected that there is more hypothesis than truth in this speculation. Be that however as it may, it is with the latter class of fruits that the world is most conversant, and in which it is most interested, and to which it is therefore most desirable that we should turn our attention. We will consider them, firstly, as to their action upon the atmosphere, and secondly, as to the nature of the changes which lead them, from being acid, austere bodies, to become the rich, sweet, fragrant, and often luscious productions, which we find in the Peach, the Orange, the Fig, the Grape, and the like.

With reference to the first of these considerations, the words of Theodore de Saussure are the only ones which it is necessary to quote. "Fruits, while green, whether leafy or fleshy," says this great observer, "act much as leaves either in the sun or in shade, and differ from those organs principally in the intensity of their action. In the night they destroy the oxygen of their atmosphere, and replace it with carbonic acid, which they partially absorb again. This absorption is generally less in the open air than under a receiver; and their volume remaining the same, they consume more oxygen in darkness when distant from ripeness than when they are approaching that state. If exposed to the sun, they disengage altogether or in part the oxygen which they inspired during the night, and preserve no trace of this acid in their own atmosphere. If many fruits are detached from the plant, they thus add oxygen to air which contains no carbonic acid. When their vegetation is very feeble, or extremely languid, they vitiate the air under all circumstances, but less in the sun than in the shade. Green fruits detached from a plant, and exposed successively to the action of the sun and of darkness, change it but little or not at all either in purity or in volume. The trifling variations that may be remarked in this respect depend either upon the greater or less faculty which they have of elaborating carbonic acid, or in their composition, which is modified according to the degree of their ripeness. Thus Grapes in a state of verjuice appear to assimilate in small quantity the oxygen of the carbonic acid which they form in the air where they vegetate both day and night; while, on the contrary, Grapes nearly ripe give back almost entirely during the day to their own atmosphere the oxygen of the carbonic acid they have formed in darkness. If there is no deception in this circumstance, which, although feeble, appears to have been constant, it marks the passage from the acid to the sweet state by indicating that the acidity of verjuice depends upon the fixing of the oxygen of the air, and that this acidity disappears when the fruit no longer seeks for carbon in the air or in carbonic acid. Green fruits decompose either entirely or in part not only the carbonic acid they have produced during the night, but in addition such quantity as may be artificially added to their atmosphere. When this last experiment is tried with fruits which are not watery, and which, like Apples and Grapes, elaborate but slowly carbonic acid, one sees that they absorb in the sun a much larger proportion of gas than the same volume of water in a similar mixture; afterwards they disengage the oxygen of the carbonic acid absorbed, and thus appear to elaborate it in their interior.

"They appropriate to themselves during their vegetation both oxygen and water, compelling the latter to lose its liquid state.

"These results are often not observ

able in volumes of air less than from 30 to 40 times that of the volume of the fruit, and by diminishing the heating power of the sun. If such precautions are neglected, many fruits will vitiate the air even in the sun by forming carbonic acid with the ambient oxygen; but even in the latter case, the simple comparison of their effect in light with what they produce under the influence of night and darkness, demonstrates that they decompose carbonic acid."

With regard to the alterations which the constituent parts of fruit undergo during the action of the preceding phenomena, and in the course of maturation, we cannot do better than reproduce the results obtained by De Candolle, from the observations of Bérard of Montpelier.

If we examine the modifications which the flesh of fruits undergoes in ripening, we shall at first remark that their fibrous or cellular tissue (which varies very much in quantity in different species) is merely lignine. In most cases, especially in very fleshy fruits, lighter, less tough, and more easily soluble in alkaline solutions than common lignine; but presenting characters of an opposite kind in other parts of the same fruit, such as their stones.

The liquid which fills the flesh of succulent pericarps consists of sap placed in the inter-cellular passages and of the matter contained in the cells. This liquid of the flesh, or of the fleshy endocarp, contains, besides a great quantity of water, sugar, gum, malic acid, malate of lime, colouring matter, a vegeto-animal substance, and an aromatic secretion peculiar to each fruit: there is, moreover, in certain cases, the tartrates both of potash and of lime, as in Grapes; and citric acid in the Lemon, and even in small quantity in the Gooseberry.

A comparison of the analysis of certain fruits before they are ripe and at that period gives some curious results. In the first place there is a disappearance of water in a liquid state, viz. per cent.—

	Water before ripeness.	Water at ripeness.
Apricots	89·39	74·87
Currants	86·41	81·10
Duke Cherries	88·28	74·85
Green Gages	74·87	71·10
Melting Peaches	90·31	80·24
Jargonelle Pears	86·28	83·88

This diminution appears to depend in part upon the fruit absorbing less water as it approaches maturity and in part upon the combination with its tissue of a portion of the water it has received. Sugar, on the contrary, appears to be continually on the increase, as indeed the taste would tell us; thus we find, per cent.,—

	Green.	Ripe.
Apricots (a trace when young, afterwards)	6·64	16·48
Red Currants	0·52	6·24
Duke Cherries	1·12	19·12
Green Gage Plums	17·71	24·81
Melting Peaches	0·63	11·61
Jargonelle Pears	6·43	11·52

This sugar is sometimes in a state more or less concrete, as in the Grape, the Fig, and the Peach, sometimes in a liquid state. It seems to be formed at the expense of other matters, the proportion of which diminishes. Thus the quantity of lignine per cent. is found—

	Green.	Ripe.
Apricots	3·61	1·86
Currants (including the seeds)	8·45	8·01
Duke Cherries	2·44	1·12
Green Gage Plums	1·26	1·11
Melting Peaches	3·01	1·21
Jargonelle Pears	3·80	2·19

It is possible, indeed, that the lignine formed in the green fruit did not in reality diminish, but that the dilatation of the cellular tissue, and consequently the augmentation of the aqueous products rendered it proportionably less, without its being absolutely so. But the gummy, mucilaginous, or gelatinous matters, appear very susceptible of changing into sugar: thus, M. Couverchel has found that if we treat apple jelly with a vegetable acid dissolved in water, we obtain a sugar analogous to that of Grapes; that the gum of Peas, placed with oxalic acid, in a temperature of 125° (Réaum.) changed to sugar; that gum extracted from starch, if mixed with the juice of green Grapes, rendered the latter saccharine; and finally that tartaric acid will produce the same effect by aid of heat: this is the reason why most fruits become sweet when cooked.

Other matters offer remarkable disparities between one fruit and another: thus malic acid keeps diminishing in Apricots and Pears, augmenting in Currants, Cherries, Plums, and Peaches. Gum keeps diminishing in Currants,

Cherries, Plums, and Pears, and augmenting in Apricots and Peaches. Animal matter keeps diminishing in Apricots and Plums, and increasing in Currants, Peaches, Cherries, and Pears. Lime, which never exists except in small quantity, seems generally to diminish, probably because evaporation becomes less with maturity.

With regard to the alterations which fruits undergo after ripening, in most instances decaying and in others bletting, there are several circumstances deserving of attention. These two states of decomposition cannot, according to Bérard, take place except by the action of the oxygen of the air, although he admits that a very small quantity only is sufficient to cause it. He succeeded in preserving for several months, with little alteration, the fleshy fruits which were the subjects of the foregoing experiments, by placing them in hydrogen or nitrogen gases. All fruits at this extreme period of their duration, whether they decay or whether they blet, form carbonic acid with their own carbon and the oxygen of the air, and moreover disengage from their proper substance a certain quantity of carbonic acid.

Bletting is in particular a special alteration; it appears that the more austere a fruit is before this is brought on, the more it is capable of bletting regularly. It has been found that a Jargonelle Pear in passing to this state loses a great deal of water (83·88 reduced to 62·73), pretty much sugar (11·52 reduced to 8·77), and a little lignine (2·19 reduced to 1·85); but acquires rather more malic acid, gum and animal matter. Lignine, in particular, seems in this kind of alteration to undergo a change analogous to that of wood in decay.

With regard to the ripening of seeds, it may be remarked that in all cases the first thing that occurs after fertilization is the closing up of the aperture of the ovule; next to which comes the appearance of the embryo, which is originally an opaque speck near the apex of the nucleus, and which at that time is surrounded by a mucous fluid, from which it seems to derive its nutriment. Although in many cases no trace is finally discoverable of a chord connecting the embryo with the point of the nucleus, yet in some instances such a communication is plainly visible, as in Zamia and Cycas, and according to Brown in Orchideous plants. As the embryo advances in size, it projects forwards into the cavity of the ovule, absorbing the fluid-matter which bathes it, till, when it is finally ripe, there is no longer any water in an unfixed state. During the solidification of its parts it gradually exchanges its saccharine quality, which seems common to all seeds when young, for the amylaceous, oily, resinous, and other secretions which are peculiar to it. It also deposits among its tissue a variable quantity of earthy matter, and of carbon, which contributes to give it a certain degree of hardness, which in some instances is of a stony consistence. All this accomplished, it acquires a greater weight than water, and consequently if ripe seeds are thrown into that fluid they will sink if they are properly matured, unless, as happens in some cases, the integuments of the seed contain air-cells, or there should be a cavity in the centre of the seed itself.

Although the deposition of earthy or other solid matter is what marks the complete maturity of a seed, yet it appears that this condition is not necessary to secure germination, for Senebier found that unripe Peas vegetated more freely than ripe ones. It rather appears to be a provision of nature to protect them from accidents, and to enable them to resist in safety the many vicissitudes they are likely to experience, after having once separated from their parent plant.

It appears, indeed, as if the longevity of seeds, that is to say the length of time they can preserve their vegetative powers, depends very much upon the completeness of the protection afforded the embryo by its integuments. Gardeners know how impossible it is to preserve very delicate seeds with thin skins more than a few weeks or months; while, on the other hand, hard, bony seeds have been known to germinate after the lapse of a great number of years. When land is cleared, or ancient ditches emptied, or earth broken up to a considerable depth, as in well-digging, it not unfrequently happens that plants spring from the mould, whose seeds must have been buried for many years or ages. Even when exposed to the vicissitudes of climate, seeds will often grow after many years; seeds of melons have been known to grow after forty-one

years, Indian Wheat after thirty years, Rye after forty years, Sensitive Plant after sixty years, and Kidney Beans, taken from Tournefort's herbarium, a hundred years after they were gathered.

It is extremely difficult to say what the conditions are under which the vitality of seeds is thus preserved, so conflicting are the statements of cultivators, and so little apparent connexion have the instances of seminal longevity with each other. It may, however, upon the whole, be inferred from the duration of seeds buried in the earth, and from other circumstances, that the principal conditions are, 1. uniform temperature; 2. moderate dryness; and 3. exclusion of light. And it will be found that the success with which seeds are transported from foreign countries in a living state is in proportion to the care and skill with which these conditions are preserved. For example, seeds brought from India, round the Cape of Good Hope, rarely vegetate freely; in this case the double exposure to the heat of the equator, and the subsequent arrival of the seeds in cold latitudes, are probably the causes of their death, for seeds brought overland from India, and therefore not exposed to such fluctuations of temperature, generally succeed. Others, again, which cannot be conveyed with certainty if exposed to the air, will travel in safety for many months if buried in clay rammed hard in boxes; in this manner only can the seeds of the Mango be brought alive from the West Indies; and it was thus the principal part of the Araucaria Pines, now in England, were transported from Chile. It may therefore be well worth consideration whether, by some artificial contrivance, in which these principles shall be kept in view, it may not be possible to reduce to something like certainty the preservation of seeds in long voyages. Such, for instance, as by surrounding them by many layers of non-conducting matter: as case over case of wood; or by ramming every other space in such cases with clay in a dry state. These means seem more likely to answer their end than the usual modes of putting seeds in bottles, packing them in charcoal, or surrounding them by coats of wax—all of which, it is well known, are absolutely prejudicial, instead of beneficial to the seeds. In illustration of what we have recommended, we may add that seeds are well known to travel best in their own pods, or pericarps; may we not suppose that their vitality is preserved in such instances by the non-conducting quality of the air which the cavities of the fruit contain?

Chapter XV.

Of Germination.

When a plant has ripened its fruit and fully formed its seeds, it has, to a great extent, fulfilled its destiny, and it has accomplished the important act of reproducing its like. It will by that time have gone through all the phases of growth, and to whatever number of years it may afterwards exist, its life will be only a repetition of phenomena that have already occurred to it.

The act of germination, therefore, which is the springing into life of a new individual, is to be considered the first period of growth, and the commencement of a future system, not the termination of an old one, as might be supposed from the subject being mentioned thus late in the present sketch.

A seed when beginning to grow presents the following remarkable features. If placed in a humid medium, and exposed to a moderate degree of warmth, it absorbs the ambient fluid, distends, bursts its integuments, protrudes a root downwards into the earth, and shortly after elevates a stem into the air. This is all that strikes the ordinary observer; but if the seed be examined more carefully, it will be found to absorb oxygen from the air that surrounds it, and to give off carbonic acid in considerable quantity. By this means it gets rid of the carbon of which it originally consists in a high degree, and its parts are softened by water and rendered more capable of extension and expansion. If a seed is made to germinate in light this happens in a less degree; but in light or in darkness it happens always. Such being the case, and such the struggle on the part of the seed to get rid of its carbon by converting it into carbonic acid, we may conclude that whatever favours or impedes the destruction of carbon during germination will be advantageous or the contrary to the function. And this explains the cause of seeds buried at great depths beneath the soil, where they are cut off from communication with the oxygen of the atmosphere,

remaining for so many years without germinating. In fact it has been ascertained by experiment, that if seeds are placed either *in vacuo*, or in an atmosphere of nitrogen or hydrogen, they will not germinate; and still less in carbonic acid. It is a remarkable circumstance, and one which is of no little interest in pointing out the wonderful foresight with which every part of the creation is adapted to mundane conditions, that after many trials it has been found that seeds germinate most freely in an atmosphere consisting of one part oxygen and three parts nitrogen, which is nearly the proportion of the air we breathe. If the quantity of oxygen is increased, the carbon of the embryo is abstracted too rapidly, and the young plant is feeble; if the proportion is smaller, carbon is not lost in sufficient quantity, and the young plant is scarcely capable of being roused into life. These facts lead us to doubt the accuracy of those experiments which seemed to prove that germination might be accelerated, or even death arrested in seeds by excess in doses of oxygen; and it is well known that, although the name of Humboldt has been enlisted in the support of such speculations, they are by no means conformable to experience.

The consequence of the destruction of the oxygen of the air by the carbon of the seed produces a sensible heat in germination, just as a similar cause produces a like effect in flowers. Hence the heat of the masses of Barley, which are made to germinate in darkness in order to become malt. And it can scarcely be doubted that the change of the starch of that grain into sugar, is equally owing to the abstraction of a proportion of its carbon, and the addition of some other proportion of oxygen.

There can be no reasonable doubt that everything that has been created has been destined for some important purpose, and consequently one would expect that every part of a seed is important to the well-being of that seed. Nevertheless, it has been found possible to deprive an embryo of many of its parts, without actually destroying its vitality. Kidney Beans will grow pretty well with only one cotyledon, or even with neither; only in the latter case the young plant is very feeble. Oaks so treated have grown for several years, but were always remarkably small and delicate. Gourd seeds have had their radicle cut away as soon as it began to fruit, and it has been afterwards incessantly destroyed as it lengthened; the plumule also has been cut away, and yet in both cases germination has gone on as usual. Of course there must be a limit to these mutilations, but De Candolle exclaims, "Where, then, is life? Where is the seat of that mysterious principle which compels all the powers of decomposition to obey its call, to change their nature, and to become powers of recomposition?" This question is so difficult to answer, that we shall pass it by in silence.

Chapter XVI.

Of the Reproduction of Flowerless Plants.

The foregoing observations have carried us, somewhat superficially it must be confessed, but at the same time consecutively, through all the principal circumstances that occur in the life of a perfect plant.

All that relates to imperfect plants, or those which are increased by simple division of their own substance and not by seeds, is equally explicable upon the same rules, with the single exception of their reproduction. Upon this head it is necessary that we should offer a few special remarks.

It must be obvious upon consideration, that plants in which there exists neither stamens nor pistils, and in which there consequently cannot take place any of those phenomena we have lately been examining, must also be destitute of seeds; for a seed is nothing but a sac of mucous matter in a particular state of organization into which either the germ of a new individual has been conveyed, or wherein its existence has been produced by some unknown action of pollen. That Nature has not, however, neglected the means of propagating the lower tribes of plants, is plain from their great abundance in favourable situations; and, upon examination, we find that, if they have not reproductive organs like those of plants of a higher organization, they are furnished with matter of another kind which answers the purpose equally well. This matter consists of what are called *sporules* or *spores*, and is lodged in parts which may be considered analogous in their function to carpels,

although they have not only no resemblance in structure to those parts in flowering plants, but also very little among each other; the spore cases being sometimes elaborate pieces of organization, as in Ferns and Mosses, and sometimes mere simple tubes buried in the substance of the plant, as in Lichens, Fungi, &c.

In the more perfect of the tribes of flowerless plants, there can be no doubt that spores act precisely like seeds in reproducing the species; for if those from the back of the leaves of Ferns, or from the urn of a Moss are sown, as they have often been, they uniformly produce the same species as that from which they were derived. In regard to these plants, then, no difference exists between seeds and spores, except as to the origin, organization, and mode of development of the latter. Instead of having their centre divided into plumule and radicle, to which one or two cotyledons are attached, they are mere homogeneous masses of cellular substance; and instead of uniformly growing from two constant points of their surface, from one upwards, and from the other downwards, they are capable of sprouting into root or stem indifferently from any point of their surface; the nature of the part the spores produce depending not upon pre-existing organization, but upon accidental circumstances. When they begin to grow, that portion of the surface which is exposed to light extends into a stem, and that which is turned to darkness and humidity becomes root. Mirbel found in his experiments upon Marchantia, that it was possible, up to a particular period of the growth of the spores of that plant, to induce the parts they had developed to change their functions, the rudimentary stem taking on itself the office of a root, and the new-born root becoming stem when their situation was inverted.

It may be considered, then, an undoubted fact that the higher tribes of flowerless plants are multiplied by their spores, and reproduce their species each after its kind, just as much as flowering plants by their seeds. But with regard to the most simple forms of vegetation, such as Fungi, Lichens, and Sea-weeds, the subject is involved in so much greater mystery, that there are to this day Botanists of no mean reputation who believe such plants to be produced by means almost analogous to equivocal generation. In their opinion there is a common matter of vegetation, of which the green matter of Priestley may be taken as the purest form, consisting of simple globular cellules, and possessing the vital principle in each cellule. They suppose that such cellules have no specific power of reproduction, but that the various forms into which they eventually grow depend upon the atmospheric and other circumstances to which the cellules may be exposed, and not to any intrinsic property of their own. Thus such matter, which exists everywhere, if called into life upon a bare wall becomes a Lichen, in a dark cellar a Fungus, in the skin of a plant a Parasite, and in water a Conferva. It is thought that several circumstances tend to show the justice of such opinions; a Conferva, for instance, is never found in any other medium than water, and a Lichen only in air. Many forms of matter are said to be uniformly productive of the same species of plant, as, for example, decayed cheese, which has always the same kind of fungi—the Berberry, the Rose, and a host of other plants, whose parasites are always confined to particular species, and sometimes to particular organs, those of the bark not being always the same as those of the leaves. If a plant of these three tribes is examined microscopically, it will be found that it is often a mere mass of cellules, exactly like the spore or reproductive cellule, except in colour; and that, even in this respect, there is not always a difference; for in such species as the Red Snow-plant the cellules are all alike in colour as well as form. It is further asserted that the power of reproduction is not confined to the spores, but exists in all the cells of which these plants are composed; and we are told, by certain German writers, that if a Lichen be rubbed in pieces, its powder will produce a *Lichen-like* plant, although the spores are not allowed to mingle with the powder. It has been shown that one supposed species of merely cellular plants is transformed into another; and that even different genera might be seen to emanate from the very same original seed. Nees von Esenbeck watched the development of a cobwebby matter which is common in the hothouses at Bonn, and he found that when the weather was dark, as in the winter and autumn, it produced

the Sclerotium mycetospora; but that, upon the return of long, bright days, Agaricus volvaceus was born from it.

If we add to these considerations the singular fact that man holds, as it were, in his hands the power of creating these things at will, at least in the instance of the common Mushroom, which will always be produced by an artificial mixture of decayed and earthy matter, it cannot be denied that a strong *primâ facie* case is made out by those who doubt the specific power of reproduction in the spores of the lowest tribes of plants, and this without having recourse to the more questionable statements that spores become plants under one set of conditions, and animalcules under others.

It is, however, by no means clear that these arguments are well-founded. Many of them are answerable upon the ground of our imperfect powers of observation, which lead us to confound forms of matter which are essentially different. It by no means follows that spores are not differently organized from simple cells, because we cannot discover the difference in their organization. Let us remember that these parts can only be distinguished with the assistance of the finest microscopes, and we all of us know how little those instruments are capable of revealing, notwithstanding all their power. Neither have we a right to say that a cobwebby substance produces the genus Agaric in the summer, and the genus Sclerotium in the winter. We, in our blindness, may think fit to draw such distinctions; but our language ought rather to be that the Agaric and the Sclerotium are different states of the same species; for are they more different than the Pupa and the perfect Butterfly? That all sorts of errors as to the genera and species of imperfect plants do exist among Botanists is notorious. Unger has shown this to be the case in Lichens; no one can well doubt that it is so in Algæ. Unger has made it clear that not a few so-called parasitical plants are mere morbid conditions of the cuticle; and with regard to Fungi in general, what has just been said concerning their metamorphoses is quite sufficient to justify our doubts in regard to the distinctness in nature of what are called the genera and species of that tribe.

As to the conversion of living matter into either animal or vegetable forms, according to the external circumstances to which it is exposed, it must always be remembered that such supposed cases have only been found to occur when common water has been employed; and it is absurd in any observers to pretend to a knowledge of what kind of elementary matter impure water may contain. It is just as likely to contain the sperm of animalcules, invisible to our senses, as the spores of plants; and this is the more probable, when we consider that no one has ever procured either the one or the other from pure water. We have before us a jar of distilled water that has been standing freely exposed to light for eleven years, and it does not exhibit a trace of organic matter.

Surely it is more philosophical, more conformable to what we really know, to ascribe the phenomena that have lately been spoken of to myriads of microscopic spores floating in the atmosphere, and dispersed by currents of air wherever that air can penetrate; and those who are practically acquainted with the nature of spores will be the least likely to question the probability of this; for they best know how inconceivably minute, how infinitely numerous, such spores really are. Even the common observer may form some notion of the fact from the calculation that millions of millions must be contained in a single Mushroom; and that many hundreds of reproductive particles are emitted by every microscopic head of the common blue mould of cheese.

Let us not, then, be led astray by specious theories and imaginary facts concerning bodies so far beyond the cognizance of our senses; but, in the absence of demonstrative evidence to the contrary, let us believe the great Author of nature to be consistent with himself in all his works, and to have taken care to enable the most humble Seaweed to be multiplied by some means as certain and unchangeable as is provided for the most stately lord of the forest. We may rest assured, for all philosophy, and all observation, and all reason prove it, that there is no such thing in nature as blind chance; but that all things have been carefully and wisely designed with reference to the particular circumstances under which they exist.

Chapter XVII.

Of Colours.

There certainly is no point of either animal or vegetable physiology now remaining to be explained of which so little is really known as the cause of the various and varying colours with which organic matter is adorned. We see in birds the plumage marked with the strongest contrasts of the most dissimilar colours, reproduced with an exactness which is most wonderful; we find the breeders of curious races able to preserve peculiar kinds of marking, and even to improve them, with the most admirable precision; we also know that in plants, without any visible constitutional change, without accident, and without any known predisposing cause, a yellow flower will become pink, and a pink one yellow; and we know that if the portion of the stem thus altered be multiplied by the division of itself, the change is fixed and may be multiplied for ever. A dingy brownish purple tulip will suddenly, and without warning, burst forth in the most radiant beauty, its dull disagreeable colours dispersed, a pure and spotless white taking its place in part, and the brightest and deepest streaks of crimson adding richness to its purity. If we look minutely to these circumstances, we shall find that each particular cell has its own colour,—that there is no intermixture of tints, but that whatever the hues may be, each has its own cluster of cells to represent it; and even in the midst of a large mass of uniform colouring, a few cells, or even a single one, will secrete a colouring matter which forms the strongest contrast with what surrounds it; as in the Blood Red Orange, and similar cases. To what causes all these extraordinary circumstances are to be ascribed no one knows. As yet our information concerning vegetable colours is of the vaguest nature. But as it is one of very great interest, and particularly deserving the notice of the philosophical botanist, we make no scruple of borrowing from De Candolle an abstract of what is at present known or conjectured of the subject.

We are so accustomed, he remarks, to see plants decorated with the most brilliant colours, or at least invested with the green hue which characterizes every scene, that it is not without difficulty that we accustom ourselves to the idea that such colours do not exist in their primitive state, but are communicated, as it were, to vegetation by its own act; and yet this is the exact truth. The tissue of plants is in itself completely colourless, of a silvery white, or of an exceedingly pale yellow; the matters contained in the cellules are, with a few exceptions, of the same hue; but all is changed when they are once exposed to solar light.

We are accustomed to say that green plants become white in total darkness, because the phenomenon, inaccurately observed, is usually presented to us under that form: but the truth is, that although the parts of plants which originally are white or black become more or less coloured when exposed to the action of light, yet that organs, once coloured, do not in reality lose their colour when kept in darkness; if they sometimes seem to do so it is owing to this,—that if half-developed leaves are placed in the dark, they grow larger, and the green matter which coloured them, being diluted by water and spread over a greater space, appears to be paler without being itself less coloured. That the action of solar light is, in reality, the grand cause of colour in plants is proved by leaves half covered from light and half exposed, of which the latter become green and the former remains colourless; all gradations of intensity being produced in proportion to the intensity of light to which the parts are exposed.

There are plants which, in those parts which are destined to become green, have spaces that preserve their original whiteness: such plants we call variegated, and find through almost all the divisions of the vegetable kingdom. In Exogens the blotches are for the most part irregular: in Endogens they are usually arranged in bands that follow the course of the principal veins. In these places it is clear that *chromule*, or colouring matter, is either not found at all or in very small quantity, but the cause of the deficiency is entirely unknown. It is, however, interesting to remark, that variegations of this kind are best preserved in sterile, and are soonest lost in fertile soil, as if they were in reality an unhealthy state of a plant,—a supposition, however, which there are no sufficient grounds otherwise for entertaining.

We have already seen that all parts which either are green or susceptible of becoming so, decompose the carbonic acid of the sap or of the atmosphere

when they are exposed to solar light, that they part with the oxygen, and fix the carbon in their own tissue. Hence it was natural to conclude that this operation is connected with the formation of a green colour. In fact, when it takes place, greenness ensues; when it does not take place, the organ which developes in darkness, preserves the primitive white colour of the tissue; and when it has taken effect incompletely, the results are intermediate between the two preceding cases.

The deposition of carbon thus induced does not act upon the vegetable membrane; that is always of its original pearly lustre. But it forms a peculiar matter called green *chromule;* the abundance or scantiness of which is what causes the different tints of leafy surfaces. The action of the membrane produces some effect, no doubt, either by reason of its own pallid hue, or its transparency or density, or of the hairs with which it is often covered, or of the air which it contains, or, finally, of the waxy matter by which they are protected. But how does it happen that carbon, which is black, is capable of producing a green appearance in vegetation? The old physiologists supposed that it is in reality an intense blue, and not a black; and that, shining through the yellow sides of the cells, the combination of the two colours produced green. This notion, however, is disproved by the most casual inspection, for the colouring matter may be separated from the tissue with the greatest facility, and it still preserves its colour; and, besides, the yellow of tissue, if any, is so excessively feeble as to be wholly insufficient to overcome the blueness of the carbon if *it were blue.* The fact is, that the cause of carbon in the system of vegetation being green belongs to that numerous class of facts, of which no explanation can be given in the existing state of human knowledge.

Although we are justified by the mass of evidence in asserting that the green colour of plants is owing to the fixation of carbon in their tissue, in consequence of the power that light possesses of decomposing their carbonic acid, yet there are some exceptions that deserve attention. Humboldt found Poa annua and compressa, Plantago lanceolata, Trifolium arvense, Wall-flower, and the Rhizomorpha verticillata green in the subterranean galleries of the mines of Freyberg, although born in total darkness, but in atmosphere highly charged either with hydrogen or nitrogen. Ferns and Mosses, again, will be green when other plants are blanched; and Humboldt found near the Canaries a Fucus which was bright grass-green, although it had grown at the depth of from 25 to 32 fathoms (190 feet.) Now, as light, according to the experiments of Bouguer, after traversing 180 feet is weakened in the proportion of 1 to 1477·8, this Fucus must have been illuminated when growing by a power 203 times less than that of a candle at a foot distance. Are we to suppose that this feeble degree of illumination was sufficient to decompose the carbonic acid of such a plant, or was not the decomposition rather owing to the operation of some unknown cause?

Leaves, which, as we very well know, are usually green, may assume different colours in special cases. It is common to see in the autumn this green change to yellow, as in the Lombardy Poplar, &c.; or to red, as in the Barberry, the Sumach, the Virginian creeper, and many kinds of Oaks. It has been ascertained by Macaire that in such cases the leaf, shortly before this change takes place, ceases to exhale oxygen in sun-light without ceasing to absorb it at night; whence he infers that the chromule is oxydized, which at first brings on a yellow and afterwards a red colour, for the most decided red always begins by a change to yellow. It is remarked that red colours are most common in leaves which contain some kind of acid, as the Vine, the Pear, the Viburnum, the Sorrel, &c. The red colouring matter obtained from leaves forms infusions which, like those from flowers, become more intense when acted upon by acids. Yellow leaves act in this manner like yellow flowers. It is supposed by some, that while red is owing to the development of acid, other colours may be ascribed to the presence of an alkali. This is however far from proved.

The same colours which mark leaves in the autumn may also be produced by certain accidents. Thus the puncture of an insect, the attacks of parasitical fungi, or injury from early frosts, produce partially or entirely yellow or red colours; and what is remarkable, the colours thus accidentally assumed are the same as the plant would have

taken of itself in the autumn: thus accidents turn the leaves of the Poplar and the Lilac yellow, of the Sumach or the Pear tree red, as they become in the autumn.

Certain leaves offer naturally on one or both their surfaces marks coloured in a particular manner, from the moment when they first unfold. Tradescantia discolor, and several Begonias have their under surface red; certain Arums are irregularly blotched with red; there are species of Amaranth which, in an apparently healthy and natural state, have leaves banded with both yellow and red. Macaire has determined that the red chromule of leaves which are thus discoloured is chemically the same as that produced in the autumn. It is worthy of note, that in regular and natural colourations red is very common, and yellow comparatively rare, although one would have thought that the latter, caused, as it seems to be, by a slighter kind of change than red, would have been the most common. Blue seems altogether excluded from changes of the leaves, except in the case of certain Eryngoes.

In many plants, the leaves which grow in the vicinity of flowers are accustomed to offer various tints, which are almost uniformly in unison with the colours of the flowers they accompany; such floral leaves or bracts are yellow in many Euphorbias, scarlet in Sages, violet in Clary, and blue in particular states of the Hydrangea. Macaire assures us that the chromule of the bracts of Salvia splendens presents the same chemical characters as that of leaves which turn red in autumn. Such bracts appear coloured because the chromule deposited in their cells varies in its degree of oxygenation, and such variations appear to be in distinct relation with the flowers. The same observations apply to many calyxes.

Why then should it be different with petals and the petal-like parts of a flower? These organs are in truth nothing but modified leaves; they are capable in particular cases, such as Hesperis Matronalis, of transforming themselves into genuine leaves, green and capable of exhaling oxygen. Can there be any the smallest reasonable doubt that these leafy petals contain in their cellules a chromule analogous to that of leaves, and consequently that when they are coloured they owe their colouring to a modification of chromule?

It is therefore probable that all the various colours of flowers, with the exception of certain special cases determined by the presence of some free alkali or acid, depend in general upon the various degrees of oxygenation of their chromule; and that this theory ought to extend to fruits and bracts where those organs participate in the same colours.

With regard to the exact relation that colours really bear to one another and to the causes that are supposed to influence them, a memoir upon the colours of flowers, published at Tubingen, in 1825, by Messrs. Schubler and Funk, is deserving of especial attention. From their account it appears that flowers may be divided into two great series—those having yellow for their type, and which are capable of passing into red or white, but never into blue; and those of which blue is the type, which can pass into red or white, but never yellow. The first of these series is called by these observers oxydized, and the second disoxydized, and they consider greenness as a state of equilibrium between the two series. De Candolle calls the first series *xanthic*, and the last *cyanic*. Upon this principle they admit the following scale, leaving white out of consideration:—

Red	Oxydized or Xanthic series.
Orange red	
Orange	
Orange yellow	
Yellow	
Yellow green	
Green	Colour of leaves.
Greenish blue	Disoxydized or Cyanic series.
Blue	
Violet blue	
Violet	
Violet red	
Red	

Which may be otherwise expressed thus—

		Green	
Cyanic or disoxydized series.	Greenish-blue	Yellow-green	Xanthic or oxydized series.
	Blue	Yellow	
	Violet-blue	Orange-yell.	
	Violet	Orange	
	Violet-red	Orange-red	
		Red	

It will be at once remarked, in considering these tables, that almost all flowers susceptible of changing colour only do it in general by rising or descending in the series to which they

belong. Thus in the xanthic series, the flowers of Marvel of Peru may be yellow, orange-yellow, or red; those of the Austrian Rose, orange yellow or orange-red; those of the Nasturtium vary from yellow to orange and orange-red; those of the garden Ranunculus pass through every gradation in the series, from red to green. As to the cyanic series, the Anemone varies from blue to violet and red, the Hyacinth from green to red through all the gradations; the Lithospermum purpurocœruleum from blue to violet-red; and the China-aster from violet-blue to violet, violet-red, and red.

Although there are certain exceptions to these rules, particularly in the Hyacinths, some of whose varieties approach the xanthic series, yet they are so far conformable to nature as to help us either in searching for the causes of colours, or in predicting the possible varieties of colour in flowers of the same species and sometimes of the same genus.

To the xanthic series belong all, or nearly all, the species of Cactus, Fig-Marigold, Aloe, Cytisus, Wood sorrel, Rose, Mullein, Potentilla, Œnothera, Ranunculus, Adonis, Tulip, &c.; to the cyanic series those of Campanula, Phlox, Epilobium, Hyacinth, Geranium, Anagallis, Globularia, &c. Hence we may assume that there is in general a relation between the colours of flowers and generic classification—an hypothesis which may be the more readily admitted when it is considered that some apparent exceptions to the cases just quoted in reality confirm the rule: as for instance, in the Campanula aurea, whose flowers are deep yellow, in a series otherwise cyanic: it is now known that this plant constitutes in reality a genus essentially different from Campanula, and called Musschia; and so with others.

It will have been remarked that white is omitted from these two series. It may be doubted, indeed, whether it really exists in a state of purity in flowers, and it seems to be rather some other colour reduced to an exceedingly light tint. Redouté, the French flower-painter, is said to have availed himself with great advantage of this fact. He always placed the flower he wished to represent before a sheet of paper like that on which he had made his drawing, and he uniformly found that the flower would differ from the paper in being more yellow, or more pink, or more blue, or in some other way. White Campanulas become blue when they are dried; infusions of white flowers in alcohol have always a perceptible tinge. Flowers which are white verging upon yellow, yield infusions which alkalies bring to a more decided yellow or a more positive brown; infusions of those which are white, tending to blue or red, become light red by the action of acids, and greenish by the action of alkalies.

It is probable that whiteness, or that kind of paleness which constitutes white, is owing to the chromule not being completely elaborated. This may be inferred, 1. from the analogy between this colour and blanched plants; 2. from the much greater number of white flowers in northern than in equatorial regions; and 3. from a considerable number of flowers which are born white, acquiring some other colour before they die, if exposed to solar light. Thus the Cheiranthus Chamæleo has a flower at first of a whitish colour, which afterwards becomes lemon-yellow, then red, slightly violet. Stylidium fruticosum has its young petals pale yellow, its old ones white tinged with red. The flowers of Œnothera tetraptera are at first whitish, afterwards pink, and finally red. The petals of the common Tamarind are said to be white the first day, and yellow the second. The corolla of Cobæa scandens is greenish-white the first day, and violet the next. Finally, Hibiscus mutabilis unfolds its blossoms in the morning white, by noon they are pink, and red at night. These changes are constant in the West Indies; but M. Ramon de la Sagra observed that on the 19th of October, 1828, the flowers of this plant remained white all day in the garden at the Havannah, and did not become pink till noon the next day. Now this 19th of October was remarkable for the centigrade thermometer not rising higher than 19°, while the ordinary temperature of the flowering season of the Hibiscus is 30° centigr.; so that it would seem that heat has some important connexion with the development of colour; and this notion is in accordance with the fact already mentioned, that white flowers are most common in cold countries.

Black is omitted in the two series of colours; it appears to be, in all cases, an excessively dark state of brown,

produced from a yellow base, or from a deep red; and is of too rare an occurrence to be deserving much consideration while so much remains to ascertain concerning commoner colours.

In red, there is this remarkable fact, that it belongs to both series; and if the theory of oxydation should be confirmed, it will appear to result from both the maximum and minimum of oxygenation. We may remark indeed that the various tints of red flowers differ much more from each other, than those of any other colour. Those which become red through the xanthic series have usually a more brilliant, richer, and more scarlet hue; while such as reach it through the cyanic series have a decidedly violet tinge. Rose, which is nothing but diffused red, may belong to both series; thus the rose colour of the Hydrangea evidently tends to blue, while that of the Rose itself appears to derive its origin from yellow. An infusion of red flowers in alcohol takes a tinge more or less red; add a little acid, and this colour immediately deepens; sometimes, as in the Pelargonium, it passes to orange. Alkalies produce the most variable results in different plants.

An examination of the two most irreconcileable colours, yellow and blue, points out some characters which are sufficiently well marked.

Infusions of yellow flowers in alcohol are of a clear yellow, without the flowers losing much colour. Acids produce no other effect in these infusions than to weaken their colour slightly. Alkalis make them more brilliant or browner.

Blue flowers produce, in alcohol, infusions either of a clear blue, as those of flax, or very dark, as in the case of the Aconite and the Larkspur. By the addition of acids they become red, and of alkalies green. Those which are coloured red by acids will not recover their blueness by the addition of alkalies, as sometimes happens to infusions of red flowers. Macaire having seen a red infusion of violets regain by degrees the natural blue of those flowers, by the addition of a vegetable alkali, such as quinine or strychnine, suspects that the colour of the violet depends upon the combination of their chromule with some alkali. Schubler and Funk assure us that the infusion of the Blue Day Lily (Funkia cœrulea), treated with an acid, will present in the same glass all the tints of the coloured spectrum. Blues are among the most changeable colours in vegetation, passing freely to white, and to different tints of violet and red.

From what has now been stated, it appears to result that modifications of chromule are the cause of the diversity of colours; and that these modifications depend principally upon the degree of oxygenation. In leaves fully developed the chromule is green; it gains a tendency to yellow or red when it is more oxydized, as one perceives by the changes of the colour of leaves in autumn by the effect of acids; and it appears to verge to blue when it is less oxydized, or, which comes to the same thing, more carbonated: thus we know that the flower of the Hydrangea becomes blue in a soil sufficiently impregnated with carbonate of iron.

All the brilliant spectacle of vegetable colours tends to disappear either in consequence of accidents or upon the approach of death; and what renders this subject the more curious is that, 1. discolouration is often determined by the same agents as, in other cases, produce colour; and 2. that certain organs which have no colour while alive gain when dead a very decided tint.

Solar light seems to be the most usual cause of those losses or changes of colours. While plants are alive, it acts, as we have so frequently seen, by colouring them; but in certain cases its too powerful action discolours them. Thus the cultivators of Tulips place their flowers under a tent, knowing very well that the direct action of the sun tends to alter their colours more promptly than would be the case in the shade. A great number of delicate flowers, particularly of those belonging to the cyanic series, exhibit this phenomenon.

Most aquatic plants gain in death a whitish hue; this is particularly remarked in Sea-weeds, which, from the most brilliant blue or green, pass to white when they die, an effect which seems to be augmented when they are exposed to air and light; but the exact mode of action of these several agents has not been appreciated. Fresh-water confervæ and several aquatic herbs present the same system of discoloration. Air evidently produces its effect by altering their chromule, probably by abstracting its carbon;

for such is the ordinary effect of the air upon dead vegetable matter. Charas, in particular, when dried in the air become quite white; this tint is no doubt to be ascribed to the alteration of their chromule, but in all probability also to the enormous quantity of calcareous matter that those plants, while alive, fix in their tissue; other cases of a like nature may be easily named. The straw-coloured hue of the green parts in a great number of dead vegetables after death depends, on the one hand, upon the oxygenation of their chromule, and on the other on the decarbonization determined after death by the action of the oxygen of the air.

Most leaves when they die are invested with a uniform russet colour; it has some analogy with what happens in bletted fruits, such as the Medlar. Such a state of the leaf may very well be owing in leaves, as well as in fruits, to an alteration in their principles analogous to putrefaction or fermentation. It is always accompanied with a great loss of water; but we have no direct evidence as to the nature of this change.

Chapter XVIII.

Of Odours.

Not less curious nor less difficult to reduce to any intelligible laws is the subject of Vegetable Odours. Our senses are daily gratified by the sweet perfumes exhaled by the leaves and flowers that surround us; and art exhausts its skill to preserve them by means which enable us always to have them present for our use; but as to the reasons why one kind of flower is odoriferous, and another scentless, we are still more in the dark than in what relates to colour. Here, therefore, we shall confine ourselves very much to a mere statement of facts, introducing theory only in cases which may appear to be pretty well understood. For this purpose we again avail ourselves of many of the materials collected by De Candolle in his invaluable *Vegetable Physiology.*

All odours are owing to the disengagement of volatile matter, and as there are few organized bodies in which, in their natural state, there is not some volatile constituent part, so neither are there many organic bodies absolutely destitute of smell. But it is only to cases in which the scent is very perceptible to our senses that we apply the idea of odoriferous, and it is consequently to those that we here confine ourselves; dividing them into *permanent*, *fugitive*, and *intermittent*.

Those odours are the most *permanent* in which the volatile matter is so inclosed in cells and concentrated as to disperse slowly. Of this many instances are afforded by wood and bark, which being in truth the only permanent parts of vegetation, will of necessity be the receptacle of durable odours; such parts are not scented, because of their own proper nature, for all the tissue of plants is originally scentless, or nearly so, but they owe their property to the fragrant secretions imprisoned in their cavities, and the permanence of their odour will be proportioned to the difficulty the volatile parts of their secretions experience in escaping through the tissue which incloses them, as well as to the degree in which the volatile matter may be fixed. Thus resinous woods, such as Cedar and Cypress, are fragrant for an indefinite period, because the resinous matter in which their odour resides is parted with slowly. Parts, whose scent resides in essential oil, preserve their scent for a long time, where the essential oil is but slightly volatile, or the wood is thick and hard: thus the Rose-wood of Teneriffe (not the Rose-wood of the English cabinet-makers), produced by Convolvulus scoparius, preserves its odour a very long time; and in order to elicit it, it is necessary to rub the wood strongly, so as to produce heat enough to volatilize the matter which is locked up in the very compact tissue of which that plant consists. The necessity of producing a little heat, in order to produce an exhalation of the volatile matter, is further exemplified by the fragrance emitted by many woods, otherwise scentless, when exposed to the violent friction of a turner's lathe: Beech is said to acquire, under such circumstances, the smell of Roses. But when, on the other hand, the volatile matter is inclosed in wood of a loose texture, neither is heat required to elicit it, nor has the wood, if exposed to the air, the power of retaining it for any considerable time, for the oxygen of the atmosphere will seize upon it rapidly, and quickly leave nothing behind but the inodorous tissue: this happens to Cassia and Cinnamon.

Fugitive smells are those which, belonging to perishable organs, are either

extremely perishable in their very nature, or are placed in tissue of the laxest kind, or are situated on the surface of plants where their volatile parts are continually abstracted by the atmosphere, or finally are secreted in quantities so small that a short exposure to air suffices to dissipate them. All these odours are produced only during the life of a plant; they are dispersed as they are formed, and after death leave no trace of their existence behind them. Like permanent odours these are continually given off, and in some plants, as the Orange and the Violet, without any variation in intensity in different states of the atmosphere; but in the majority of cases the power of the smell will vary according to the elevation of temperature, and the dampness of the air. This fact must be familiar to all who are acquainted with gardens. In the hot, dry weather of a summer's noon, flowers either become scentless, or at least lose a large proportion of their usual fragrance; and in walking through a wilderness of the most sweet-smelling plants, we find little sign of their odour, unless they are bruised or trampled upon. But if a heavy shower should come on, all will be changed in an hour's time; every leaf, every flower, will emit its peculiar odour; the Musk plant (Mimulus moschatus) will fill the air with its singular scent, and it will be obvious that the addition of moisture to the air has produced a total change in the action of the odoriferous organs of plants.

The same phenomenon is daily repeated in the driest days of autumn. Those only who are accustomed to take their early walks abroad can have any idea of the difference between a richly-stored garden early in the morning and at noon. When the sun has dried the air, and has been beating for some time upon vegetation, ill able to bear his action in consequence of the dryness of the source from which they draw their means of compensating for evaporation, however beautiful a garden may still remain, it cannot be compared to the same place before the dew has dispersed—when every herb, tree, and flower is pouring forth a stream of the most varied and delicious fragrance—when the air is impregnated with the most delicate balsamic odours—and when all nature seems as if offering up incense in gratitude for the refreshing powers of darkness and of dew. Let any one, for example, visit a thicket of Cistuses at noon, and again the next morning, and the difference will be exceedingly apparent. To what cause this is owing is unknown; possibly the effect of dryness and excessive heat may be to close the stomates, and to contract the tissue of plants, thus rendering it difficult for volatile matter to pass through their cuticle: it may also act by depriving them of the necessary proportion of water required to enable them to perform their functions of secretion and assimilation, and thus arrest for a time the elaboration of the fugitive principles upon which fragrance depends. While, however, dew and showers, with intervals of bright light, are eminently favourable to the eliciting of vegetable perfumes, a continuance of wet and gloomy weather, without much sunshine, is as greatly unfavourable. This latter circumstance is explicable upon the general law of physiology, that secretions cannot be readily produced without the direct assistance of the sun's light.

With regard to what we call *intermittent* odours, no explanation seems possible in the present state of our knowledge. A few examples of them will therefore be all that we can give. All dingy-flowered plants, such as botanists call *tristes*, belong to this class; such as the Pelargonium triste, Hesperis tristis, Gladiolus tristis, which are almost entirely scentless during the day, but become deliciously fragrant at night. Great numbers of Orchideous plants have flowers possessing the same property; the Catasetums have a fine aromatic odour at night, none in the day, except C. purum; Cymbidium Sinense is also chiefly fragrant at night; and so with a great many more. Cestrum nocturnum is another plant of the same nature; in the day it has no odour, at night its perfume is extremely powerful. One of the most singular instances of exceptions to all rules appears to be referable to this class: Cacalia septentrionalis exhales an aromatic odour if exposed to the direct rays of the sun, and if anything is interposed between it and the sun its odour disappears, but is renewed as soon as the interference is removed.

Agreeable as vegetable odours usually are to our senses, there are some striking exceptions. Many Stapelias, the Arum dracunculus, and several other species of the same genus, whose

flowers are of a deep livid colour, have a smell so completely that of putrid meat, that flies actually deposit their eggs in them by mistake; Arum trifidum has an abominable stercoraceous odour; and the pollen of the Sweet Chestnut and the Barberry has a peculiarly disagreeable smell. Even the most delicate kinds of fragrance when concentrated prove disagreeable, and in many cases, in their simple state, act powerfully upon the nerves; even oil of Roses highly concentrated can scarcely be supported, and every one knows that a perfumer's shop, although the receptacle of the sweetest essences, is by no means an agreeable place. The spasmodic affections produced by the odours of flowers are more common than is generally supposed, but vary in different individuals according to their respective powers of endurance. Some of the most remarkable cases are the following:—The Jonquil and the Tuberose are insupportable by persons of delicate nerves; few can bear the fragrance of the Lilac, especially in a room; even Violets, the last flowers to be suspected, have in many cases proved deleterious; De Candolle says he has witnessed many ladies faint from carrying too many of them on their persons, or from having placed them too near them when asleep. It is asserted that people have died from being shut up in a room in which the Oleander was in flower; hysterics have been brought on by the Musk Mallow; Saffron has been known to produce swooning; and the flowers of Lobelia longiflora have caused suffocation. The odours of other organs may also produce inconvenient consequences: the Elder, the Walnut, and the Anagyris bring on headache in persons who sleep beneath their shade; and the Manchineel tree is said to have proved fatal to travellers who have trusted to its shelter.

Vague and unsatisfactory as all these details must be admitted to be, they are so connected with one of the most curious inquiries in either the vegetable or animal kingdom, that we think we cannot have done otherwise than render good service to our readers by letting them form a part of this treatise, especially as they are scarcely to be found adverted to in our English elementary works; and we close what relates to the physiology of plants, by strongly recommending the investigation of the subject to all those whose tastes, leisure, and attainments may lead them to occupy themselves with one of the richest fields of inquiry which yet remain in Nature to be explored.

Part III.*—Systematic Botany.

Chapter I.

Of the General Nature of the Plan that is followed in classifying Objects.

When an observer first sets himself to examine the various plants with which the earth is clothed, he finds his attention forcibly arrested by their great diversity of structure, and by the seemingly endless variations under which nature presents herself in a vegetable form. The first meadow that he enters will bring before him a crowd of individuals, which, although at first sight all so similar that they might be looked upon as one large assemblage of the same form of vegetable matter, yet, upon a more exact inspection, prove to consist of endless variations of structure: some will be found to have netted, others striated leaves; some to bear their heads erect in the form of green scaly cones, while others bring forth gaily coloured cups, and another set, without either cones or cups, creep along the ground, and seem as it were to form a carpet for the floor of that vast enclosure in which so many millions of vegetable beings are assembled. Upon a yet nearer inspection, it is found that this mass of individuals, confused as it seems, may be abstracted into groups that agree with each other in every petty detail of structure; and that the scene consists of nothing but such groups excessively intermixed; these groups are *Species*. As soon as the mind has thus assorted the species, it becomes evident that there are groups among them also, having certain other attributes in common by which they differ from one another; these are again mentally assorted, and form abstractions of a higher order called *Genera*. If the field is extensive enough, genera will themselves next be put into groups distinguished in the mind of the observer by some other qualities that they possess in common, and *Orders* are the result. And thus, by a series of abstractions of different degrees, in each of which the "distinguishing peculiarities are lost sight of, and attention is limited to those attributes which belong to the individuals in common," a classification of some kind or other is arrived at. If, in such a supposed case, the observer should judge among the individuals correctly of all the points of agreement or disagreement that really exist between them, and should have placed them in his mind near or distant according to the nearness of their agreement, or the greatness of the sum of their differences, he will have formed a *natural* classification; that is to say, a classification in which those individuals will stand nearest each other that are most alike, and those be stationed farthest apart which are least alike. If, on the other hand, he should have erred in this respect, and have abstracted the individuals according to certain single characters, and not according to the sum of them, he would have formed an *artificial* classification.

But as, in either case, he would, in the first instance, have abstracted the individuals according to what would have appeared to him their identity, and so assorted the whole into species, and as he could hardly commit any considerable errors in that respect, seeing that no great doubt would be likely to arise as to what constitutes identity, it would follow that species would form the basis of his classification, whether natural or artificial.

This is precisely the course that is taken by Botanists in assorting the vast mass of individuals with which the face of the earth is beautified; they first combine the individuals into species, next arrange the species in genera, then collect the genera into orders; and thus, by successively losing sight of differences, and confining their attention to points of agreement, they finally reduce the whole to a regular classification.

It is obvious, however, that this kind of progress must be arbitrary and uncertain in the highest degree, unless some rules are laid down for determining what is to be considered the relative value of the differences that must be employed in classification; and such a necessity has given rise to that department of the science on which we are now to treat, in which undoubtedly there is, from the very nature of the subject, much that is vague, but in which there also is much that is well deserving the attention of the philosopher.

Under any circumstances it is desirable, that in instituting an inquiry to be conducted by numerous independent observers, certain rules should be agreed upon, and certain prin-

* Descriptive Botany, which it was originally intended should form the third part of this Treatise, will occupy the fourth part.

ciples settled as the basis of their investigation, otherwise, however limited the field of observation may be, there is a danger of the results being attended by such discrepancies as will vitiate and render useless all the labour that may be expended. That it is more especially important for this to be done in Botany, is manifest, if we consider how very numerous are the species that constitute this vast section of the animated world; how endless are the varieties of their structure; how liable they are, from their very nature, to shift and change their appearance, according as they are influenced by this or that combination of external influences.

What number of species of plants may really exist upon the earth will possibly never be known. At present there is no means of forming even an approximative estimate, so little has been effected in the examination of a large portion of the globe, and so imperfectly are we acquainted with the results of the examination that has been hitherto made.

Professor Lindley estimated them in 1835 at about 86,000, but this is probably much too low, and it seems that we should be justified in carrying the number up to 100,000. Meyen raises the number to 200,000 (*Pflanzen Geographie*, p. 5).

Chapter II.

Of Species and Varieties.

According to Jussieu and others, a species is a combination of individuals alike (*semblables*) in all their parts. De Candolle makes it "a collection of all the individuals which resemble each other more than they resemble anything else; which can by mutual fecundation produce fertile individuals; and which re-produce themselves, by generation, in such a manner that we may from analogy suppose them all sprung originally from one single individual." "The first unity after individuality;"—"a systematic combination of homogeneous individuals;"—"a collection of individuals which will breed together, and produce fertile offspring," are other definitions. In order to understand these rightly, and to see how they apply, it is necessary to separate the definitions into two parts, the one comprehending the structural, the other the physiological characters assigned to a species.

So far as these definitions depend upon structure, they seem to amount to this, that all individuals which are identical, constitute in the aggregate a species. It is therefore necessary to inquire what is here meant by the term "identity." It is manifest that it is not employed in its strictest sense; for there probably never was even one pair of plants of the very same size, form, or colour, in all respects: the word must therefore be taken to bear a more extensive application.

All plants are considered botanically identical in which the structure *nearly* corresponds. For example, if one individual has leaves two inches long, and another, those parts three inches long, the two would, nevertheless, be considered identical, provided they corresponded in all other respects; nor is it here that the identity contemplated in the previous definitions can be said to stop. If one plant has white flowers and pale green leaves, while another has blue flowers and dark green leaves, but are otherwise the same, they would still be considered identical: or the word may be applied yet more widely; for suppose one fruit-tree bore small round sweet apples, red flowers, and shining leaves, and another bore large angular acid apples, white flowers, and opaque leaves, nevertheless, and notwithstanding these differences, the two would come within the idea of identity, provided their differences went no farther. The reason of such a latitude being given to the application of the term is, that in plants many external characters are of a fleeting and transitory nature, as is known by experience, and such transitory characters are not taken into account in comparing two individuals. Of that nature are, in general, colour, taste, size, and, sometimes, even form. The seed of a plant with white flowers may produce an individual with blue ones; or the seed of an acid fruit may give birth to a plant bearing sweet fruit. These are facts ascertained by experience, and therefore all such peculiarities are in general estimated as unimportant in determining the collection of individuals into species.

Botanical identity must hence be understood as meaning a correspondence in all *permanent* characters. The application of this rule depends entirely upon the knowledge and judgment of the botanist, and is unfortunately liable to much uncertainty, from a variety of causes, depending upon the specific

peculiarities of different plants. What is permanent in one species is transitory in another; and what is transitory in one is permanent in another, for no known cause. For example, the colour of the flowers is liable to variation, and consequently unimportant in Campanula, Pyrus, Hyacinthus, and others; but it appears permanent in the genus Mesembryanthemum. The presence or absence of hairs is of no permanency in Rosa, Pyrus, Rubus, &c., and yet it is generally found a distinction of value in other plants. The form of the fruit is notoriously variable in Pyrus, Cucumis, Prunus, and others; but in Carex, Mitrasacme, &c. it is found constant. The leaves too, which in their form are uncertain in Eucalyptus, Dahlia, Pyrus, and some few genera, often afford excellent discriminative marks. For these reasons it is perhaps impossible to decide with certainty what is a species upon structural differences alone.

The physiological definition of a species is, that all the individuals that belong to it will breed together and produce successors having the same power of reproduction by seed. This idea has evidently been derived from the animal kingdom, in which, among the higher orders of animals at least, it seems liable to no exception. In plants it is exposed to two objections; firstly, it is inapplicable to by far the largest part of the vegetable kingdom, for we possess no means of ascertaining whether species will breed together or not, except in the case of the few that are immediately within our reach in a wild or cultivated state; and secondly, it implies that no individuals will so breed together, except those which belong to the same species, a statement of which we possess no means of ascertaining the truth, and which seems opposed to experiment. It would hardly be doubted, that the wild wood Strawberry of Europe is distinct as a species from the American kind, *Fragaria Virginiana*, for they are different in their foliage, in their flowers, in their fruit, and in all their habits, yet they certainly will breed together and produce fertile offspring; and numerous similar cases of Pelargonia, Gladioli, &c., are upon record. It may, however, be alleged that all the well ascertained cases of this kind are really instances of the intermixture of strongly marked varieties of the same species; that the wild wood Strawberry of Europe is not more different from the American than a Shetland pony from an Arabian horse; and that moreover, as it is certain that the definition applies to many species that are distinct beyond all dispute, as the Apple and the Pear, the Gooseberry and the Currant, it is probable that it applies in other cases as well.

Be this as it may, it is at least certain that the physiological definition of a species is merely theoretical, and that the only one which is applicable to practical purposes is that which is derived from organic identity, as above explained. But it has already been shown, that it is impossible to determine what is a species upon structural differences alone, and hence it may seem impossible to decide the question by any certain rule whatever. And that is the truth; let botanists explain, and define and refine as much as they will, they are driven at last to admit that whatever theoretical limits may be assigned to a species, there are none of a positive kind; but that the determination of the point must after all be left to the experience and judgment of the observer.

The rules that are to be attended to in forming a judgment in this matter may be stated thus: species are not usually distinguished by differences in the internal organization of individuals, or in the plan upon which their external parts are combined,—those circumstances are not taken into account till genera and the higher assortments of species come to be formed; but upon differences of a superficial and external kind, or such as are independent of internal organization.

The cause of the same species varying in regard to such points as these has been well stated by De Candolle. "Let us suppose, what really happens, that the seeds of plants are scattered at hazard over the surface of the earth, or, to speak more correctly, by causes that have no necessary connexion with the existence of those plants; such seeds will find themselves in an infinite variety of situations; some which have fallen in soil that is too tenacious or too loose, too dry or too wet, too hot or too cold, do not grow and are soon destroyed. But between these extremes, some will succeed, although it may be under very different circumstances. Thus, for instance, if the place is not light enough, the plant will be half blanched, as will be indicated by its

paleness and feebleness, or by being spotted, or by the diminution or even loss of its hairs; if the light is too bright the plant will be stronger, dwarfer, more deeply coloured, harder, and more velvety than usual. Temperature also exercises some influence, though in a less degree; in a cold climate the same plants are smaller and weaker than ordinary; the colour of the flowers and fruits is paler, the wood worse ripened, their leaves more deciduous, their fruit often abortive, and the sap destined to nourish it, throwing itself into the neighbouring parts, sometimes changes their appearance. In a hot climate plants become larger, produce more wood, and their leaves have brighter colours, and a higher flavour. In the same climate humidity causes the appearance of differences without end; plants that grow in water lose all their hairs, their leaves become divided into capillary segments so as to look like hairy roots; their stems and flower stalks lengthen to reach the surface of the water; and these different effects are still further variable as the water is still or agitated, clear or turbid, pure or mixed with heterogeneous substances; the varieties of *Ranunculus aquatilis* offer a remarkable example of this. If, on the other hand, a plant accustomed to water is found to live in a drier soil, it becomes covered with hairs, remains smaller than usual, and acquires greater hardness. In air rarified like that of mountains, plants are generally found smaller and more stunted than usual, while their flowers are larger than upon the plains. The influence of soil is not less manifest; if it is tenacious, the roots, which penetrate it with difficulty, remain small, hard, and clustered; if it is very sandy, the roots become large, fleshy, and fully formed; if it contains a great quantity of carbon, the colours of the flower are often altered, as those of the Hydrangea into blue, and of the Pink into violet; if it is charged with salt, or if the plant is within the reach of salt, even brought through the atmosphere, we usually find the leaves more fleshy and more glaucous, as in *Lotus corniculatus*. All these different circumstances, combined with each other in nature, are fertile causes of varieties, which are still further multiplied by cultivation."

To these causes of variation has to be added an inherent tendency in certain species to throw off one peculiarity, and to assume another as often as they are propagated by seed. Experience is the only guide to the discovery of such variations, and herein much of the advantage of a practised over an unpractised botanist consists; for the latter knows that certain peculiarities are not permanent, not as a point of theory, but as a matter of fact, independent of all theory. He knows, for instance, that if the seeds of the *Anemone coronaria* with white flowers are sown, they will produce individuals with flowers of many other colours; that if Purple Beech seeds are sown, they will form plants with green, pale purple, and deep purple leaves; or that whenever a bed of seedling plants of any long cultivated species is examined, a number of discrepancies will occur among them, either in their flowers or their leaves, or some other part.

The particulars upon which species are usually distinguished are:—1. *Duration;* 2. *Dimension;* 3. *Surface;* 4. *Form;* 5. *Division;* 6. *Numerical Proportion;* 7. *Colour.* We will consider the value of each of these separately.

Duration comprehends three spaces of time only, namely duration for a period defined by the production of flowers and fruit, after which the individual perishes: these are annuals; duration of the roots for an indefinite period, the stems flowering and fruiting, and perishing annually: these are perennials or herbaceous plants; and duration of both roots and stems for an indefinite period, the latter not perishing after the maturation of the fruit, but becoming woody and giving birth to new stems (branches): these are shrubs and trees. It may be taken as an universal rule, that individuals differing in points of this kind are specifically distinct. It is not indeed probable, that differences of so important a kind as these, which are inherent in the very nature of the individuals, and which could not be altered without an alteration in their whole physiological condition, should be of a transitory kind; it is almost certain that the very few cases in books where a plant is said to be annual in one of its varieties and perennial in another, are mere instances of botanical errors. There is no proof to the contrary of this in the common Mignonette, which is annual in England, and a kind of undershrub on the coast of the Mediterranean, nor in other such cases; for the Mignonette and

plants of a similar kind are not in reality, when in our gardens, at all different constitutionally from the wild species, but they are incapable of enduring the cold and wet of winter; and hence, as they produce their flowers and fruit in a few months, they are only treated as annuals in such countries as England; if they are kept in a greenhouse they preserve all their native habits unaltered, and become small undershrubs.

Dimension is rarely of importance even in extreme cases; a plant only a few inches high in a poor dry soil may become very much larger in a damp rich soil; the effect of cultivation is to increase the dimensions of plants in all their parts, or sometimes even to diminish them, as is the case in the numerous dwarf varieties of common species, found in every garden. We have Dahlias reduced in stature by dwarfing from six feet to two feet; *Dianthus barbatus* from eighteen inches to three inches, and even Spruce Firs, in the case of the Clanbrasil Fir, reduced from timber trees to a pigmy bush. And a similar result occurs from climate: it is well known that many of the trees of plains become more and more dwarf as they ascend mountains, till at length they become mere underwood, and the same thing is true of herbaceous plants and annuals. It sometimes, however, happens that differences, not in general dimensions, but in those of particular parts, become of specific importance, as, for example, in the case of two individuals resembling each other in most respects and growing in different soils, of which that growing in damp rich soil bears small flowers, and the other in dry sterile soil bears large flowers. Distinctions of even this sort are, however, to be distrusted under any circumstances; for the usual size of flowers may either be increased by a portion of them being destroyed when the nutriment intended for many is directed to the support of one, or diminished by the production of many more flowers than usual, when each flower has but a sparing supply of food.

The *surface* of individuals is sometimes remarkably dissimilar, the difference arising from several distinct causes, of unequal value in judging of identity. Surface is sometimes what is technically called rugose, in consequence of the parenchyma between veins being convex. This is an invariable character if contrasted with smoothness,—that is, a flatness of the parenchyma; but it is apt to run into a greater degree of convexity when leaves become *crisp*, or *bullate*. It will be found, upon examination, that all such leaves are variations of a rugose surface; *Mentha crispa*, for example. In like manner, if an individual is marked by having its veins projecting above the parenchyma, it is never referable to a species whose veins are level with the parenchyma. Some plants have their surface so smooth as to seem polished: this is a constant character; and of the same value is the presence of asperities in the form of tubercles, or hard-based hairs, originating below the parenchyma. These, as well as glandular hairs, secreting something at their points, are indications of constitutional peculiarities, which the species never loses or alters, under whatever circumstances it may be placed. Thus, in the difficult genera, Rosa and Rubus, those individuals in which secreting or glandular hairs exist, are apparently referable to species essentially distinct from those in which no such hairs exist. Far otherwise is it with common lymphatic hairs, which, as has already been shown, may appear in greater or less abundance upon the very same individual, according to the different circumstances in which it is placed.

In the common Dog Rose (*R. canina*) we have leaves entirely destitute of hairs; other individuals with a few hairs on the midrib; others with them spread over the whole lower surface; then again they overrun the upper surface, and thus produce diversities of appearance which have led to the creation of many spurious species. It may be considered a certain rule, that in all cases differences in the degree of hairiness of individuals are unimportant if unaccompanied by further differences in other respects; nevertheless, the terms denoting the presence, or absence, or quantity of lymphatic hairs, are in constant use among the best systematists; because, as the appearances produced by them are of a very obvious kind, they are convenient indications of distinction when combined with other circumstances. These observations apply chiefly to leaves; hairiness of the stem is far more constant; and where hairs of any kind appear upon parts that are usually destitute of them, as, for instance, the co-

rolla, the stamens, or the ovary, such circumstances are usually a permanent indication of species. It has also been thought that the direction in which lymphatic hairs point, may be taken as a good specific character; and this has been applied to the genera *Myosotis* and others, but it is doubtful whether this is right*. The presence or absence of prickles, which are a form of hairs, is apparently of certain value in extreme cases, or in comparing wild plants with each other; but its value is much diminished when wild and cultivated individuals are objects of comparison; for it not unfrequently occurs that prickly species become unarmed when introduced into gardens, as has happened to Rosa alba, in a very prickly genus. The surface of a plant is sometimes covered with a slight waxy glaucous secretion constituting *bloom*. A good deal of value is attached by Botanists to this mark when it appears, and it often proves of much use in determining doubtful points; as, for example, in defining the limits between *Aster cyaneus* and *A. rubricaulis*.

The *form* of different parts is often one of the most delusive characters, although in many cases it seems to be of value. De Candolle well observes, that as to the general forms of organs, "they are only of importance as they are the consequence of anatomical differences; that is to say, of the arrangement of the veins. The form of a leaf may vary within tolerably wide limits, without any material change in the arrangement of its veins." In fact, nothing is more common than striking differences in the form of the foliaceous organs in the same species. The gardens are filled with narrow-leaved, broad-leaved, long-leaved varieties, well known to have been raised from the seed of species in which the leaves are altogether different. The entire-leaved Ash, a most remarkable tree, is a striking instance of this. Its leaves are ovate, and simply serrated. The common Ash has pinnated leaves, and yet there seems no doubt that the seeds of the entire-leaved Ash will produce the common pinnated state of the species, and that consequently the former is a mere accidental variety of the latter. In general, however, differences in the form of the organs of fructification, provided they are well marked, are constant, except in the case of succulent fruits, the form of which is very changeable and uncertain.

Characters, derived from differences in the degree of *division* of organs, are to be distinguished into two classes: 1. those which depend upon mere lacerations of the parenchyma of the same organ; and 2. those which arise from the non-adherence of contiguous organs. To the first class belong all toothings, or lacerations of the margin of leaves, petals, &c.; and these, in the leaf at least, are seldom of any consequence, provided they are merely different in degree. For instance, the common Alder (*Alnus glutinosa*) usually has leaves with a mere serrated margin, but sometimes they are pinnatifid, or almost pinnated; and this is a common circumstance. Hence, the numbers of cut-leaved, fern-leaved, and similar varieties of plants, common in gardens. It is less usual for leaves which are quite entire to separate into divisions, but even this occurs in the *Symphoria racemosa*, the young vigorous shoots of which are sometimes covered with deeply sinuated leaves, while those of the remainder of the bush have not a trace of division. Lacerations of the margin of petals are usually constant, as between fringed and fringeless cases; but if there is any laceration at all, mere differences in degree are to be distrusted. The second class of differences includes all the modifications of division observable in the calyx, or corolla, &c., and generally these are very uniform in all individuals of the same species.

Numerical proportion has been well disposed of by one of the most learned of modern botanical writers. "Differences," says De Candolle, "in the number of parts demand the most serious attention on the part of the naturalist, either because their importance has been often exaggerated, or because this importance is sometimes very great, and sometimes very small. In the midst of such anomalies, let us attempt to reduce it to its just value. General differences in the number of stems, branches, leaves, or flowers, have scarcely ever any importance, unless in extreme cases, or as between unity and some high number, or when special observation has shown that certain numbers are constant. Thus the number of leaves or flowers in a whorl may vary by 1, 2, or 3 above or below the

* De Candolle states that the form of hairs is in general very constant in a species, but it forms a character that is hardly ever attended

customary number; but the greater the difference becomes, the more attention must be paid not to confound different things. On the other hand, there are certain plants in which certain numbers appear constant; thus *Convallaria bifolia* has constantly two leaves, *Trillium sessile*, three, *Paris quadrifolia*, almost always four, &c.; *Tulipa Gesneriana* bears but one flower on a stalk, *Lonicera Xylosteum* always two; *Cytisus triflorus* usually three, *Litsea tetranthus* four, and so on. With respect to this, we ought to take as a general rule, in objects of number in Botany, that *the number of organs or of parts is most subject to variation, the greater it is.* Although we know of many exceptions to this rule, it is nevertheless sufficiently constant to serve as a guide in practice. The absolute number of the parts of flowers and fruits comes within the preceding observations, but nevertheless deserves more confidence than that of other organs; it is rare for differences in these parts to exceed one *plus* or *minus*, and therefore care should be taken to determine their number with precision. We must moreover be on our guard against natural adhesions and accidental abortions, which in certain cases may mask the real number. But number becomes a character of high importance, when such changes, instead of being absolute, are relative; that a plant with four petals and four stamens should take five petals and five stamens, is common enough in the same species; but if, preserving the four petals, it should change the number of stamens, we then obtain an important character, provided always that we are not deceived by accidental adhesions and abortions."

With regard to *Colour*, it is probably of all the differences by which individuals are distinguished from each other, the least important; and as a general rule it is to be left out of consideration. Nevertheless there is one point of view under which it becomes a less fallacious guide. From some unknown cause, the tendency of particular colours is to change in certain directions, but not in others; as for example, blue into red or white, but not into yellow; and yellow into green or scarlet, or brown, but not into blue. (See page 122, &c.) When therefore we have to compare two individuals, much alike in other respects, but the one with yellow flowers and the other with blue, the probability is that they are two distinct species. There are moreover certain genera in which colour seems fixed in particular species, as in Mesembryanthemum, and Aconitum.

Odour, *taste*, and similar qualities, are by themselves of no moment whatever; they are owing much more to the peculiar circumstances under which a plant may be placed while growing, than to any specific property. For instance, aromatic plants become more aromatic as they are exposed to the powerful action of bright light in dry places, and less so, as the situation in which they grow is shaded; an acid fruit on a north wall becomes a sweet fruit on a southern exposure; celery growing in ditches developes its dangerous extractive principle, and becomes deleterious; but in a dry garden it is incapable of developing it, and becomes an agreeable salad.

These statements are purposely confined to points upon which there can be no difference of opinion, and they serve to show in a striking light, the excessive absurdity of species-mongers, who constitute a species out of every trifling variety in the surface, form, dimensions, or divisions of the organs of plants; and who, by such a proceeding, not only embarrass science with numberless names, but introduce the greatest confusion into the distinctions of genuine species. We will quote a few striking examples of this practice. The genus Salix is fixed by Mr. Borrer at 71 British species; Koch and Lindley have reduced them to 29; Rubus is reported to have 21 British species; it can hardly be doubted that they are all reducible to 8, if not to 6 genuine species. The number of Austrian Menthas is raised to 44 by Host: Mr. Bentham has shown that they ought to be diminished to 10. Rosa was stated by Mr. Wood to comprehend 22 species, mostly distinguished by the single or double serrations of their leaves, the density of their prickles, the surface of their fruit, the hairiness of the leaves; of these 14 only at the utmost can be allowed as genuine. It is inconceivable to what an extent this evil of multiplying species upon insufficient characters has in modern times been carried, especially among the third-rate Botanists of Germany. *Veronica*, *Viola*, *Salvia*, *Scabiosa*, and almost all large genera, have passed through their hands, and now require to be again ex-

amined by some Botanist of sound judgment and sane mind, in order to be restored to an intelligible state. There is at this moment in a Botanic garden near London a collection of Rhubarbs divided by a worthy Spanish Botanist into fifty or sixty species; and yet there is no evidence to show that the gardens really contain, at the outside, above six or seven genuine species. This is mere childishness, or scientific fatuity.

No plant can be considered a species that is not capable of being characterized by *several clear, permanent, well-defined marks*, by which it will be distinguished from all its neighbouring species; it can very rarely happen that one single character is all that exists as a difference between two species. To say that this plant differs from that in having its leaves rather more cordate at the base, or slightly hairy underneath, or linear-lanceolate instead of oval, or its branches many-flowered instead of few-flowered, and so on, is merely to point out the existence of certain differences, and by no means to show that such marks belong to specific distinctions. Theodore Helm, who is supposed to be the expositor of the systematic views of Professor Mohs, the celebrated mineralogist, has made some good observations upon this point. "If I have two straws before me, of which one is six inches long and the other seven, I can distinguish them perfectly by that circumstance; and two plants otherwise alike, one with six and the other with seven flowers, may be well and certainly distinguished by those marks of number only, and so on. *But let me ask, are these natural-history differences? (differentiæ physico-historicæ); are they not altogether distinct from the principles of natural-history; and do not they obviously come within the idea of systematic identity? (homogeneitas.)*" It is greatly to be regretted, that we should so often find length, and breadth, and size, and the like, referred to in the works of men of *Science* (*?*), as affording characteristic distinctions; it is still more to be regretted, that the length, breadth, and so on of all these parts, should be most minutely and carefully reduced to inches and lines; and it is perfectly lamentable to find upon record distinctions such as these. "This *Sisyrinchium*, formerly confounded with *S. anceps*, certainly differs from it in having its spathes *more* short than the flowers, its stem *less* compressed, its leaves *more* wide, its flowers *more* large, and mixed with blue and yellow; finally it is a *native of a different country*, and cannot pass the winter *out of a greenhouse*, while *S. anceps* lives all the year long in the open ground. *Eucomis punctata* resembles *Eucomis regia* very much, but it differs principally in its leaves being long*er*, narrow*er*, and *more* pointed, in its scape being high*er*, and its spike twice or thrice *as long*, and terminated by *much shorter* leaves."

One fertile cause of the perplexity that has been introduced into specific distinctions, has been the artificial creation of *hybrid plants* in gardens, and their natural production among wild plants. The former is a notorious occurrence; the latter has been denied altogether; or admitted in a few special cases, such as certain Gentians, Saxifrages, &c.; but is probably a very common circumstance. It has been argued that as mules are almost unknown among animals in a state of nature, they should be equally rare among plants; and that in both kingdoms they only occur among species in a state of artificial life, resulting from domestication. But it seems to us that this matter has not been well considered. If mules are rare in wild animals, that circumstance may be accounted for by the fact, that intercourse between animals is an act of instinct, and that an antipathy to intermixture with other species may be supposed to be implanted in the nature of all animals. But in plants there is no such thing as instinct; there is no power of avoiding one thing and searching for another; plants cannot travel from place to place in search of their mates; but where they stand there must they perform all the functions of their life, communicating their influence, be it what it may, to all bodies in their vicinity, and in their turn receiving the influence of others. Suppose two willows of distinct species standing near each other, and a gust of wind or a bee brings the pollen of one to the stigma of the other, what is to hinder that pollen from fertilizing the seed of the female; or the seed thus created of an intermediate nature between its two parents from falling to the ground, and then giving birth to an individual intermediate in its character between the male and female parents. It is quite plain, that the intermixture must inevitably take

place, and that in this manner something that had never been seen before will be produced. And there is no physiological reason whatever why this should not very often occur. It is true that the mule being barren will perish again in the course of time; but before it has disappeared it has been gathered, dried, and deposited in the herbarium of a Botanist, or, if a woody plant, it has been dug up, transferred to a garden, multiplied by cuttings, layers, &c., and dispersed through the gardens of all the finder's friends, as a *new species*, of the discovery of which he claims the *honour;* and then it finds its way into books. What is to be done with this vegetable monster? surely it ought not seriously to be raised to the rank of a species; and yet we find hundreds of things of such an acknowledged origin in the works of even De Candolle himself (see his *Prodromus Regni Vegetabilis*, vol. i. page 649), to say nothing of other cases; certainly we ought not to do this unless, indeed, we consider the Spanish mule a species distinct from the Horse and the Ass, which would be too absurd; we ought rather to strike them all out of systematic works, and to leave them to the care of the gardener, or those others who are interested in the preservation of such productions.

It is however a very embarrassing subject, this natural production of mules; for there is no known means of determining at first sight whether a plant is a mule or not. Professor Henslow found that a mule Digitalis did not exhibit the slightest anatomical organic difference from its parents. There is no means of judging with accuracy, even if the observer is acquainted with both its parents; and it is manifest that if acquainted with neither, or only one, the difficulty is still further increased. In some genera, as Rosa, in which the species cross each other very readily, the intermixture has been carried so far, that intermediate states may be produced from the most stunted state of *Rosa spinosissima* to the most gigantic form of *Rosa canina*. Willows, and probably many other large genera, are in the same predicament. From such cases as these, where no precise limits can be pointed out between species, some naturalists have proceeded to argue, that in reality species have no existence, that the vegetable world is a mere mass of individuals which we may arrange into groups called species, according to their likenesses, but which have no distinct qualities, and that the supposed limits between them are altogether arbitrary and imaginary. We think, however, that no necessity exists for this violent supposition, and that whatever evidence there may seem to be of its truth in particular cases, it is more than outweighed by other evidence. Take, for instance, in one of the most variable of genera, *Rosa*,—take the seeds of the common Sweetbriar, and sow, as we have often witnessed, an acre with them. All the plants in that acre of land will be botanically identical and referable to the same common form of *R. rubiginosa* from which they sprang. Probably not a single plant in all that acre will exhibit even a trace of a tendency to vary. Look again at the thousands of acres of Turnips that are annually raised in this country: who ever saw any instance of the slightest tendency on the part of those turnips to be any thing except the species Brassica Rapa, unless in those cases where the seed had been notoriously obtained from the intermixture of the pollen of the cabbage, or some allied species? And suppose such a monster to be created, either it produces no seed and perishes for ever, or, if it produces seed, that seed being sown, will produce plants returning to the species B. Rapa, from which it sprang. To deny the existence of species then, because of difficulties in determining the limits that separate them, is, independently of all other considerations, to argue in the face of the plainest evidence of their real presence. Naturalists are much more worthily employed in clearing up the difficulties that exist in the way of distinguishing species, than in accumulating doubtful instances of their transition into one another; a most mischievous theory directly opposed to the general evidence in both kingdoms of nature, "and useless, because, if it were true, we should be compelled to act as if it were false, under penalty of knowing nothing, and to study the habitual forms of vegetation just as we now do."

With regard to the uncertainty and difficulty that is obviously connected with the discrimination of species, De Candolle has some excellent remarks, the substance of which we shall borrow as a conclusion to this discussion. If the doubts that often exist as to the real

limits of species were as common as at first sight they seem to be, they would not only throw beginners into despair, but discourage the most consummate naturalists. But by a law that seems strange, though in reality it is very simple, nature has confined this indefinite tendency to variation to the most common species, or to those which are most extensively cultivated. For what in fact is a rare plant? It is a plant which is so organised, that it can only live in a particular locality, and which perishes in all others; such a plant is incapable of assuming different forms. What, on the other hand, is a common plant? It is a plant robust enough to exist in very different localities, and under very different circumstances, and which will therefore put on many different forms. Those first variations, once established, may be multiplied and increased, by hybridizing or other causes, and will become numerous in proportion to the quantity of individuals that may be created. Cultivation is one of the most efficient causes of the production of varieties, either because it multiplies so very much the external circumstances that surround a plant, or because, by bringing plants together, it increases their opportunities of muling. But a rare plant, that is, one which requires a particular locality, cannot be generally cultivated, and is thus cut off from the great source of variation. These considerations suffice to show, that plants are liable to run into varieties in proportion as they are more robust, more common, or more cultivated; as for instance, *Lotus corniculatus*, *Anthyllis vulneraria*, *Pyrus communis*. They also explain why certain exotics are more easily cultivated than some of our own native plants, such as Gentians, Pedicularis, and the like.

We cannot terminate this very important subject more usefully than by quoting some observations upon species by Mr. Bentham, a most sagacious and successful investigator of their real value in the order Labiatæ (*Lamiaceæ*), upon which an inconceivable amount of systematic trifling has been expended. "There seems every reason to consider that each species has a really distinct existence in nature, as a group of individuals, varying from each other only within the limits of individuals descending from one common stock; and the question is therefore here, *are* two plants of the same species or not? Of this it is seldom we can obtain positive evidence; we must reason by analogy — we must take into account all the varieties likely to be caused by soil, climate, and other external agents,— by cultivation, by hybridity, by disease, &c., as well as by the age and period of development of the specimen before us; — we must consider whatever circumstantial evidence we can deduce from station, from abundance of individuals resembling each of the two specimens before us, or from any other source we can get at; and from these data we must then form our judgment. This judgment may indeed be erroneous, even when pronounced by the most experienced Botanist possessed of the greatest number of data; how much more so must it be when a young Botanist, scarcely acquainted with the commonest plants of his own neighbourhood, sits down with a scanty library in a botanic garden, and publishes as new every specimen that does not exactly coincide with the descriptions of the plant whose name he finds appended to his specimens; or if, studying the wild plants of his own country, having no general herbarium, and therefore ignorant of the various forms a species may assume in other countries, he considers as specific distinctions any accidental variations to which a continuation of the circumstances which originally occasioned them may give, in his neighbourhood, a certain degree of permanency.

"I have been led into these observations as a sort of answer to those who may consider me presumptuous in setting up my opinions, formed, in a great measure, from dried specimens, against the observations of local botanists and directors of botanical gardens, often of great merit, who have studied the plants living. If, for instance, the principles upon which M. Host added 37 *Menthæ* to the Flora of Vienna were to be followed throughout, the number of Labiatæ now to be described would rather be 17,000 than 1700; these 17,000 descriptions would most of them, a hundred years hence, have to be replaced by as many others, and the whole would soon become a complete chaos. Already, many of the original plants upon which M. Host established his species, and most of their descendants, no longer possess his distinctive characters; and if this be the case with M. Host, how

much more must it be with those who, with all his national pride in the number of species comprised in his Flora, have none of his talent, and carry to so high a degree the sometimes mercenary and always foolish vanity of tacking so many *nobis* to botanical names.

"Some genera of Labiatæ are peculiarly liable to this multiplication of species. Very hardy and abundant in those parts of Europe where the real number of species has long been well known, the same species, growing in a great variety of situations,—in the dry roadside dust or in marshes, or even in water—in shady woods and in open commons—long cultivated in gardens, and carried out to all parts of the world—not only casual varieties, but more or less permanent races, have been formed in the *Menthæ*, *Thymi*, *Stachydes*, &c., which it is impossible with any certainty to distinguish from real species; and any disposition to make species may readily be indulged in to almost any extent. Hybridity, also, that great obstacle to the discrimination of species, is not unfrequent in *Mentha* and *Thymus*, and probably in some other genera; although in the greater number of Labiatæ, fecundation taking place at the moment of the expansion of the corolla, and the parts of fructification being more or less concealed, hybridity only ensues under very peculiar circumstances.

"Another great difficulty that occurs, in long-known variable genera, in distinguishing the species, is the impossibility of judging, from the numbers seen in herbaria, of the real proportion in the number of intermediate forms to that of each of two common forms which they connect. If a whole tract of country be covered with individuals of two distinct forms, with here and there some accidental intermediate, it is these intermediates that the collector will seize upon with avidity, almost neglecting the normal states, and, at any rate, neglecting to record the fact of their great disproportion."

Chapter III.

Of Genera, and of the Principles upon which they should be constructed.

Supposing species to be distinguished in the clearest manner, it would be impossible to study them as isolated objects; the human mind would never be able to comprehend so vast a multitude of distinct forms of vegetable matter. And indeed it would soon be obvious to the most superficial observer, that to attempt so impossible a task is unnecessary, for in many cases, species obviously collect into small well-defined groups, having certain common characters of agreement, notwithstanding their respective points of differences. Roses, Heaths, Clovers, Cinquefoils, Brambles, are familiar instances of such self-evident combinations; and it is found that similar, though perhaps less manifest groupes are to be met with throughout the vegetable kingdom, so that the whole number of species, large as it is, may be reduced to 7000 or 8000 such assemblages: these are genera.

A genus has been defined to be a collection of species which have in common a striking resemblance in the totality of their organs; or a collection of species resembling one another, more than they resemble anything else. It might perhaps be better described, for the above are anything but definitions, as a collection of species agreeing in the number, proportion, and general nature of the organs of fructification; and then every genus will be the representation of some special, simple type of organization, which differs from all other types; just as an order is the representation of some more compound type of organization?

Descriptions of this sort are necessarily vague and indefinite; and hence a great uncertainty in what should be considered the true limits of many genera, and an arbitrary mode of constructing them, that has led to much confusion. While some Botanists, as Linnæus, and most of the older writers, comprehended under one name extremely different kinds of structure, because of some common character that connected them, others, on the contrary, have constructed their groups upon such trifling distinctions, as to render the words species and genus almost identical terms. Both these classes of writers have been equally in the wrong.

Although we do seem to recognize genera, apparently ready-formed, amongst the vast mass of vegetable productions, yet it is quite certain that in a very large majority of cases they are mere contrivances to enable us to execute the first process of analysis,

by which the vegetable kingdom is systematized. Now the writer who constructs genera upon trifling characters, and thus reduces genera back into species, defeats the object we have assumed to be pointed at in constructing such groupes; they do not assist us in the process of analysis, and therefore are objectionable. On the other hand, the Botanist who combines plants with extremely different structures under one generic name, renders useless the analysis to which he leads us, by depriving his genera of any definite or intelligible meaning. It is clear that the right course is between these two extremes.

De Candolle maintains the somewhat singular doctrine that so long as a group of plants is *looked upon* as a mere section of some other assemblage, it may be considered one genus; but if it should turn out that it has been wrongly so looked upon, and that it forms a special assemblage of the next higher grade, namely an order, it may then be subdivided into a number of genera. If this really were so, it would render the limits of genera much more arbitrary than they really are, which hardly need be. But we think this doctrine cannot be supported. One would say that if plants differ essentially in structure, as the various groups of Lichens for example, they ought to be esteemed distinct genera, whether they together form a section of an order, or an entire and special order; and that the reason why Botanists formerly admitted such genera as Lichen, Orchis, Epidendrum, Geranium, &c., was, that they did not know of the remarkable diversities of organization that are now found to exist among their species.

Perhaps the best way to judge what a genus really is, may be to take such notoriously indivisible genera, as Rosa, Rubus, Fragraria, Potentilla, and Geum, and see by what it is that they are so positively combined that no one is now able to devise a method of subdividing them. Probably their example may be more instructive than the best verbal definitions.

In Rosa the calyx has a fleshy tube contracted at its orifice, with five leafy segments; the corolla consists of five thin coloured petals; the stamens are extremely numerous, and arise from just without the contracted orifice of the calyx; the carpels are numerous, distinct, one-seeded, hairy bodies, each having a single style and stigma, and all enclosed within the tube of the calyx, except the stigmas which project beyond it; the fruit is formed by the tube of the calyx becoming succulent, and the carpels change to bony seed-like nuts enclosed within it. The numerous legitimate species of this genus disagree in the form of their leaflets or the number, and in the nature of their prickles; some bear fragrant glands upon their leaves, others have their fruit armed with stiff bristles; others have the segments of the calyx equal, instead of partly unequal; and some again bear their flowers singly in the bosom of common leaves, instead of originating from bracts. Here then is a group of plants uniform in the plan of organization of their fructification, but differing in certain modifications of those parts, and of the organs of vegetation.

Rubus has the general characters of Rosa, only its calyx is *not contracted at the orifice* into a hollow chamber to contain the carpels, and never *becomes succulent*, but remains thin and dry to the last; its carpels, on the contrary, *have a succulent coating* when ripe, and are disposed upon a *conical dry receptacle* that projects beyond the open mouth of the calyx. Here are several important peculiarities that never occur in Rosa; and agreeing in such common characters is again a large number of species, some with simple, some with compound leaves; some with herbaceous, others with woody, some with unarmed, others with prickly stems; some having their leaves of one form, others of another. Rubus then is essentially distinguished from Rosa. Now, suppose, what really happens in Rosa Rapa, that a plant, *otherwise agreeing in all respects* with Rosa, has a campanulate calyx open at the orifice, could such a plant be separated as a distinct genus? Such an idea never has entered the mind of any one; for no one could pretend that such a difference could be of equal importance with those which separate Rubus from Rosa.

In Fragaria we have the structure of Rubus, except that the calyx consists of *two rows of sepals* instead of one; the carpels are *dry instead of succulent;* and the *receptacle succulent instead of dry;* in other words, the power of collecting fluid and saccha-

rine matter, which in Rosa exists in the calyx, and in Rubus in the carpels, is here transferred to the receptacle. These are very important differences connected with vital functions; and are manifestly of a higher order than diversities in the form, surface, and texture of the leaves, or the relative hairiness of different parts, by which the species are distinguished.

Then Potentilla is a Fragaria in all respects, except that its *receptacle is dry, not succulent.* Here indeed the difference between the two genera is confined to one single character; but then it is a character connected with the uses to which the species have been destined, and it indicates a total change in the nature of an important organ. Its numerous species are distinguished by peculiarities in the foliage, the stem, or the inflorescence, and in the *external forms* of the organs of fructification.

As for Geum it differs from Potentilla solely in its *styles becoming rigid and hooked,* instead of shrivelling up or falling off. This too is a single character, but what an important one it is! The style, a most essential part of the fructification, changes its office after impregnation, and, from being a fertilizing organ, becomes a peculiar means of disseminating the seeds to whose organization it originally contributed. Subordinate to this particular are strongly marked differences in the leaves, the calyx, the inflorescence, which indicate a number of species agreeing in the common character of the hardened style.

As a further illustration of this subject, a few spurious genera may be advantageously cited. Take the modern characters of Stachys and Betonica, two Linnean genera.

Stachys. Calyx ovate-campanulate, 10-ribbed, with 5 somewhat unequal mucronate teeth, the throat naked or somewhat naked. Corolla hardly projecting beyond the tube, with a prominent, entire, concave upper lip, and a lower spreading trifid one.

Betonica. Calyx between conical and tubular, 10-ribbed, with 5 equal mucronate teeth, the throat beset with stiff hairs. Corolla with a slightly curved tube projecting beyond the calyx, an ascending upper lip, and a lower hanging 3-lobed one.

What can be more slight than the differences between these? One has the calyx a *little more* campanulate, the teeth *rather less* equal, the corolla *rather longer,* and the throat of the calyx a *little more* hairy, and the lower lip of the corolla *rather more* pendent than the other. Nothing can be more trifling or unimportant than such distinctions. The two supposed genera are one and the same. It is upon similar puerile distinctions that the genus Trifolium has been divided into seven or eight by Presl, Erica into 14 or 15 by Don, and Œnothera into 10 or 12 by Spach. These are blots upon the face of science by which she is disfigured and disguised. In all such cases the authors have mistaken trifling superficial characters for fundamental, structural, or physiological ones; this, although it may seem a mere verbal distinction, is in reality a most important one.

Mischievous however to science as are the proceedings of mere genus-makers, hardly less injurious are those of persons who, clinging to old prejudices, would preserve the heterogeneous genera of our forefathers in their ancient state. Orchis, for example, they would keep as Linnæus left it; but the genus Orchis of the great Swedish Naturalist comprehends plants with many different contrivances for effecting impregnation, and with whole series of organs in one species which do not exist in another, and all these constitute particular categories of organization under each of which many species arrange themselves. There is no distinct meaning then in the Linnæan word Orchis, to which precision has only been given in modern days.

We again quote some practical remarks by Mr. Bentham upon this subject. Speaking of the course he has taken in his monograph of *Labiatæ* (Lamiaceæ), he says:—

"For the distribution of Labiatæ into genera, I fear I shall by many be accused of inconsistency in the importance I have attributed to the characters I have selected on different occasions, but this appeared to me unavoidable; for, although, as a general rule, certain characters are of an order superior to others, yet, in detail, there are too many exceptions in nature to allow a graduated scale of characters to be drawn up with any exactitude. Take an instance from one of those of the greatest importance, the entire or four-lobed ovarium, a distinction which, with scarcely any exception, draws a line

between two very extensive and natural families, the Verbenaceæ and Labiatæ. Apply the same rule to Borragineæ, and you must separate *Heliotropium* from *Cynoglossum*, *Cynoglossum* and *Echinospermum* from *Anchusa* and *Myosotis*, when a series of species might be selected from all these genera so near to one another in habit and other characters as to tempt one at first sight to consider them as forming but one genus.

"If I have, therefore, for example, on some occasions taken differences in the calyx, in the anthers, &c., as generic distinctions (the anthers of Sphacele and Stachys, the calyx of Thymbra and Melissa); at others, considered them merely as sectional or even specific distinctions (the anthers in Melissa, the bilabiate calyx in Stachys menthæfolia), it has been because, in the one case, they appeared to me constantly accompanying differences in facies and other characters, and at other times at variance with them. Besides which, I have always considered, that although certainly we do observe certain groups of plants more nearly allied to each other than to any others, and distinguished from their several affinities by a sort of hiatus, yet even now, many as are the species which remain to be discovered, it is often very difficult to say between which two species the hiatus is most marked, and the more plants we discover the more are these hiatuses filled up. A genus, therefore, has seldom any existence in nature as a positively determined group, and must rather be considered as a mere contrivance for assisting us in comparing and studying the enormous multitude of species, which, without arrangement, our minds could not embrace. But although our genera be not in nature, yet the nearer we follow what is in nature in grouping our plants, the more useful is our labour. Whenever two or more species resemble each other by all those characters which experience has shown us to be important, they should form a group of the lowest order. Where several groups resemble each other closely, but differ in some character of an order rather higher than those with which we separate species, they form a group of a superior order; and these again form groups of a third order, and so on, till we arrive at the general group Plants; but to which of these orders of groups we give the name of *genera*, and to which those of *order*, *tribe*, section, &c. is a matter of mere convenience.

If all existing plants were known, and it were always possible to say to which of the 1st, 2nd, 3rd, &c. order a group belongs, then it would be absolutely necessary to take care that the name *genera*, for instance, should always be given to groups of the same order; but in the present state of the science, at least, this is impossible. Take, for example, the group of Nepeteæ, which is very natural because a very marked one, offering (as at present known) no intermediates with others in regard to its essential characters; it comprises two groups distinguished from each other by slighter and more variable characters. One of these comprehends four of a still lower order; of these Nepeta comprises eight groups of a fourth order; and another (Dracocephalum) contains five, which are about of the same value as the eight of Nepeta, but which might be distributed into two or three intermediate groups. It would be just as natural to consider the whole of these as one genus, consisting of two sub-genera, seven sections, and eighteen sub-sections; or as two genera, one comprehending two sections, and the other four sub-genera and sixteen sections; or as I have done, as a tribe, containing two groups, one with a single genus, divided into two sections, the other with four genera, two of which are subdivided into sections; or if each of these sections were considered as a genus — provided that in all cases no groups be collected into one of a superior order, that are not more like each other than to any other group. Whenever, therefore, natural affinities appeared to leave it indifferent which of two courses I should pursue, I have, with few exceptions, considered as sections such groups as are distinguished by characters of no greater importance than stem, foliage, or inflorescence; and all characters taken from the organic structure of the parts of fructification have been considered as generic."

Nothing has, probably, given rise to so many heterogeneous genera as the famous Linnean axiom, a genus shall furnish its own character, but no genus can be founded upon a character (*Genus dabit characterem, sed non character genus*). That is to say, when a collection of similar species has been formed, some common character by which they may be combined is to be sought for; but a

peculiarity of structure is not to be first selected and then the species collected under it. It was apprehended that the latter practice would lead to the formation of merely artificial genera, and it was expected that the former would ensure the generic groups, being so natural that they might be recognized at first sight, independently of their technical character. De Candolle regards this axiom as the touchstone by which the goodness of genera is to be estimated. "It is by it that we are principally able to determine what are the really essential characters of each natural order; for instance, the calyxes of the larger species of Gentian possess strongly marked differences which would readily seem to form several genera; but the extreme resemblance of these plants one to the other obliges us to leave them united, and proves that the form of the calyx is of no importance in their order." (*Théorie élémentaire*, ed. 2, p. 220.) Helm has sustained the proposition metaphysically, considering it of the utmost importance, and the very foundation of scientific knowledge. (*Dissertatio de Methodo physico-historicâ*, p. 78.) And to this we must add the authority of Fries. "In the formation of sections and genera it is most especially necessary to beware that they do not depend upon characters alone; so that if the character should hereafter prove defective, the section or the genus may still remain unchanged. In this lies the difference between an artificial and natural arrangement; the former depending upon characters, the latter upon affinity. Hence Linnæus did not characterise his families of plants, nor Ehrenberg those of Fungi, rightly perceiving that affinity is of the first importance, characters of secondary." *Syst. Mycol.* — Professor Lindley has however objected to it, and we think with reason. "Whether or not," he says, "this proposition is to be admitted, depends entirely upon the nature of the character employed; for if the character is one of fundamental importance, it is absolute, and that which defines the group; but if it is unimportant, it is unfit for any sectional purpose and ought to be rejected. For instance, to have their trunk growing in the centre is the character of Endogens; and who would think of removing from those plants Smilax or Dioscorea, because the appearance of the latter is that of Menispermum, or some Euphorbiaceous genus among Exogens (?)" (*Nixus Plantarum*, p. 4.) We follow on the same side.

It is said that after a genus has been made by collecting together a number of species greatly resembling each other, a character is to be found to combine them; that is, in the first instance a genus is to be formed upon some vague and indefinite notion of natural resemblance, and after that has been accomplished, a positive combining character is to be discovered. But we would ask what is meant by a natural assemblage, or by strong botanical resemblances? unless a strict correspondence in organization; and what can so strongly indicate that, as conformity in fundamental points of structure, or, in other words, in important characters? Botanical resemblances depend then for their very existence upon what Linnæus called a character, and therefore it seems to us that his proposition should be reversed, and that we ought to say that *characters form the genus, and not the genus the characters.* If we are to trust to vague external resemblances for forming a preliminary idea of a genus, all scientific precision is abandoned. A common observer sees a great and close similarity between an Ash Tree, a Walnut Tree, and a Sumach Tree, or between a Hazel Bush (*Corylus*), a Witch Hazel (*Hamamelis*), and many Grewias; but in reality these plants, however natural their grouping may seem to be, have no botanical affinity, but merely correspond in certain unimportant superficial particulars. On the other hand, a common observer can see no great resemblance between the common European Nettle and many of the arborescent Nettles of the Tropics, and he would never dream of their forming a natural genus; and yet they really correspond in every one of the essential characters of their organization. Let no one take alarm at this heresy; for if important characters are made the basis of generic distinctions, no unnatural or heterogeneous assemblages can be the result; the necessary and inevitable consequence of employing important structural characters, *independent of all other considerations*, is the collection into genera of species resembling each other more than they resemble any thing else. This is proved in the clearest manner by the genera so constructed by Brown, De Candolle, and others, the highest

modern authorities we have. Brown has divided his New Holland Epacridaceæ, Orchidaceæ, Cyperaceæ, Myoporaceæ; De Candolle his Brassicaceæ, Apiaceæ, Cinchonaceæ, and Compositæ entirely according to their structural characters, and not according to the general appearance of the species; but the latter coincides with the former as we have asserted that it would; and we attribute the great and universally acknowledged excellence of Brown's generic characters to his having virtually abandoned the Linnean axiom now in discussion. And so have and must all writers who would lay any claim to precision. When the Linnean method is adopted, the consequences are of the following nature: A plant is discovered which is in reality organically distinct from all known genera; but it has some *resemblance* in structure to a known genus, and it *looks a good deal like it;* the botanist who follows up the maxim of Linnæus stations the plant in that genus, although it is essentially at variance with the character of the genus; and at the same time gives it a name which does not belong to it. This is as if, in society, a person were to call his son John Brown, because he resembled an acquaintance whose name was Brown, although his own name was John Green; in such a case no one could discover that John Brown belonged to the family of John Green. Here the absurdity is obvious, and yet it is not seen when applied to Natural History; or we should not have in the writings of botanists such passages as the following upon the occasion of placing a plant in a genus with whose character it does not correspond. "I refer this plant to the genus Eumorpha, in consequence of its great resemblance in habit to Eumorpha patens and grandiflora; it must be confessed, however, that its fructification is far from corresponding with that of the genus in question." That is to say, it is referred to the genus, *although it does not belong to it.*

While we thus contend against the principle of combining dissimilar things because of some vague common point of agreement, we would nevertheless caution the student against embarrassing the science by a display of his ingenuity in detecting little characters by which it is possible to break up old and long recognized genera into smaller groups. After all that can be said concerning the limits of genera, and the principles upon which alone they ought to be constructed, there must still be something in those principles vague and undefined, and which must be left to the judgment of the systematic botanist; and therefore expediency may occasionally be consulted in doubtful cases. There is very great inconvenience in changing the names of large numbers of species, as must be done in extensive alterations of old and long established genera; for example, the spurious genera created by one Spach in a silly scheme for remodelling the genus Œnothera, would cause for that one genus the abolishment of 49 names and the creation of 63 others. Proceedings of such a kind increase extremely the necessarily very considerable difficulties connected with so intricate a branch of science as systematic botany, and therefore should be taken with great caution and only in cases where they cannot be avoided: for so long as such a word as Œnothera has a precise value, there is no inconvenience in employing it, even although it should appear that a possibility exists of making it something more precise; while there is the greatest practical inconvenience in admitting so many changes in nomenclature as its subdivision would render necessary. But when we find a man introducing confusion by cutting up a well defined homogeneous and long established genus, because in some species the seeds have a thicker skin than in others; because the seed-vessel is in some narrow and in others broad, in some tough, and in others tender; in some 4-ribbed, in others 8-ribbed, and in others 12-ribbed; when we find a man acting thus — we may, without much risk of error, set him down as a verbal trifler, of unsound judgment, with no general views, and who is incapable of perceiving the distinction between fundamental differences of organization and slight modifications of one and the same type of structure.

In order to ensure some uniformity in the construction of genera, it is usual that whatever in any one natural order is taken as a generic character for one genus, should be also taken for all other genera *in the same order;* as for example, when in Orchidaceæ the number of pollen masses is within certain limits taken as a distinctive mark of certain genera, similar differences in number in the same organ should be

looked upon as absolute in all other genera of the same order. In the words of De Candolle, "whenever a particular character has been employed to separate a certain number of genera, it ought to preserve the same importance in all similar cases, that is to say, it must, according to circumstances, either unite genera separated by a single character, or separate species from genera to which they would have been referred if it had not been for that character; thus in Compositæ, botanists are agreed in admitting a setaceous or a feathery pappus as absolute distinctions of certain genera: those modern writers have consequently been right who have broken up certain genera of Compositæ in which species with both setaceous and feathery pappus had been heaped together." To the justice of this doctrine we cannot but assent; for it is the only certain means of rendering generic distinctions consistent and of the same value in the same natural order. It must, however, be observed that in proportion as this doctrine is absolutely pressed upon the botanist, does it become requisite to ascertain that the distinctions thus taken as peremptory indications of genera are unquestionably important, otherwise false genera without end will be created. For instance, what numberless genera of Cruciferæ, Umbelliferæ, and Compositæ will have to be suppressed, if it should ever be discovered that the characters of the embryo, the vitæ, the albumen, or the double pappus of those orders respectively, are of less value than they are now estimated at!

When genera were first put into their modern form by Tournefort, that botanist drew their characters partly from the fructification and partly from the organs of vegetation. Linnæus, on the contrary, repudiated the latter as uncertain, and insisted upon the necessity of attending exclusively to differences in the parts of fructification; and his example has been very generally imitated. Nevertheless, this rule may be followed too rigorously, for, as Jussieu has truly remarked, "it is not always conformable to nature, which not unfrequently places certain characters in the stems or leaves above others taken from the stamens, or the pistil, or the floral envelopes. Thus, the character of opposite leaves is more constant in Valerian and Gentian than that of the three stamens, in the first of those genera, and of five in the second. The leaves are always alternate in the Larkspur and the Pæony, but the number of their ovaries is variable. The corolla is both absent and present in Ashes and Maples, but those trees have universally opposite leaves." These instances, which might readily be increased, suffice to show that several characters in the fructification are sometimes of less importance than others which are independent of it.

With regard to the value that is assignable to the different peculiarities by which genera are to be characterized, this depends so very much upon circumstances, that it is rather a matter to be determined by experience than regulated by certain laws. Nevertheless the following rules are deserving of serious consideration:—

1. A character is important in proportion as it is connected with modifications of function.

2. A character is unimportant in proportion as it is connected with modifications of texture, proportion, number not in extremes, form, and the like.

3. Excellent distinctions are those connected with numerical proportion, absence or presence of certain classes of organs, relative position, decided differences in the degree of adhesion of organs, regularity and irregularity, high developement or low developement, tendency to loss of parts, and so on.

4. "Characters are not to be estimated as so many units, but each according to its relative value; so that one single constant character may be equivalent or even superior to several inconstant ones taken together."—*Jussieu.*

Tried by rules of this sort, not a few long-established Linnæan genera may be found wanting, as in Silenaceæ and perhaps Malvaceæ; but this will, we think, in the eyes of botanists, rather attest the goodness than show the invalidity of such principles.

Chapter IV.

Of Orders; Alliances; Groups; or other systematic Combinations subordinate to Classes.

It has already been said, that while a genus may be understood as the representation of some special simple type of organization, an order is the representation of a more compound type of organization to which the genus is sub-

ordinate. In reality, orders, groups, alliances, or by whatever names such assemblages are called, are combinations the one of the other, formed upon the same principles as genera, and may be considered as genera of ascending importance. As there are genera which, like Rosa, Quercus, and Rubus, seem actually to be formed by nature herself, although others are confessedly artificial assemblages, so are there orders like Galiaceæ, Apiaceæ, Brassicaceæ, and alliances like Echiales, Chenopodales, and Lamiaceæ, and groups like Labiosæ, Aggregosæ, and Glumosæ, which bear a similar impress of original separation from the others that surround them. Nevertheless we are only justified in considering all such combinations as assemblages of genera, orders, or alliances which resemble each other more than they resemble any thing else.

Such words as genera, orders, alliances, groups, &c., are then conventional terms, having the same general meaning, and differing only in degree, just as villages, hundreds, counties, kingdoms, and empires, or any such relative expressions. So true is this, that many of them have been genera in the eyes of former systematists; instances of this are Fungi, Ferns, Palms, Grasses, Lichens, Mosses, &c.

In the construction of these groups, the great point is to keep steadily in view the necessity of preserving a strict conformity in the essential parts of fructification, and not to confound mere instances of analogous organization with real affinity. Affinity is indicated by an accordance in all points of structure, except such as are taken as discriminative of genera; analogy consists in an accordance between one or two parts only. If this is not attended to, errors without end are the inevitable result. Thus when Professor Don allowed himself to be deceived by some analogies between Menodora and Columellia, he committed the error of uniting in one order a plant which in reality belongs to Jasminaceæ, and another that comprehends a special and peculiar type of its own; and most of the cases of errors about the natural orders to which plants belong, are referable to the same cause; witness Calycandra, a leguminous genus placed in Capparidaceæ; the curious genus Moringa, once referred to Leguminosæ; Lutkea, a Rosaceous genus stationed in Saxifragaceæ; Adoxa, an Araliaceous genus, till lately kept in Saxifragaceæ, and so many others.

Chapter V

Of Classes; and the Nature of the Characters upon which they are founded.

Classes are the fundamental divisions of the vegetable kingdom, representing the largest aggregations of species, and expressing the most essential combining characters which they possess. They are by many considered merely as a higher order of division, and analogous to orders, alliances, groups, and so on. While, however, the latter are indisputably mere artificial groups of naturally related genera, it seems probable that classes have some real existence in the original plan of nature. As in animals, the great classes of Quadrupeds, Birds, Fishes, Reptiles, and Insects, stand like isolated groups, which might almost be considered independent kingdoms; so do Exogens, Gymnosperms, Endogens, Rhizanths, and Acrogens, each also appear to be created by nature as altogether independent forms of organized matter.

The distinctions of groups like these are not confined to mere variations in certain types of organization, as is the case with the assemblages subordinate to them; but they are founded upon corresponding differences in the manner of growth, of propagation, of circulating the fluids, of reproduction, and even of elementary anatomical structure; in short they depend upon peculiarities connected with their whole nature, and not with mere modifications of particular parts.

If this distinction is a just one, we think it can hardly be doubted that the great fundamental divisions of the vegetable kingdom are altogether of another nature from the subordinate ones; and that while the latter are necessarily to a certain extent artificial, the former are literally natural, and a part of the original plan of the creation. This perhaps may be made clearer by a comparison.

The *class* of Exogens is

1. Constructed with both spiral vessels and cellular substance.
2. Furnished with sexes.
3. Grows by augmentation of the diameter of the axis.
4. Propagated by seeds.
5. Germinates from two definite points of its embryo.

The *class* of Acrogens is

1. Constructed of cellular substance chiefly, without spiral vessels.
2. Destitute of sexes.
3. Grows without augmentation of the diameter of the axis.
4. Propagated by spores.
5. Germinates indefinitely from any part of the surface of the embryo.

Every one of these five peculiarities is connected with the habits of life, manner of growth, or power of multiplication, that the plants in these two classes severally possess. Contrast with these the distinctions between two of each of the assemblages of different degrees, subordinate to the classes and above the genera.

A. The *sub-class* of Monopetalous Exogens has	The *sub-class* of Polypetalous Exogens has
1. The petals combined into a tube.	1. The petals distinct from each other.
B. The *group* Epigynosæ of Polypetalous Exogens has	The *group* Parietosæ of Polypetalous Exogens has
1. Ovary inferior, with either parietal or central placentæ.	1. Ovary superior, with parietal placentæ only.
C. The *alliance* Onagrales of Epigynous Exogens has	The *alliance* Myrtales of Epigynous Exogens has
1. All the parts of fructification symmetrically disposed upon a binary type.	1. The parts of fructification unsymmetrical.
D. The *order* Combretaceæ has	The *order* Alangiaceæ has
1. Petals short and roundish.	1. Petals long, linear.
2. Anthers versatile.	2. Anthers adnate.
3. Albumen absent.	3. Albumen fleshy.
4. Cotyledons convolute.	4. Cotyledons flat.

We have been constrained to take these cases from Professor Lindley's Natural System, because no other English botanical writer has attempted, upon any fixed plan, to depart from the artificial subdivisions of Jussieu and De Candolle. Such examples are, we presume, sufficient to show that there is an essential difference between the classes and other divisions of the vegetable world.

Chapter VI.

Of the Transitions that are observable between the different assemblages in the Vegetable Kingdom.

That there is no such thing in nature as an abrupt transition (*saltus*) from one thing to another, has long been a favourite speculation with philosophers, and has not failed to be applied to natural history. Ray, in the preface to his "Historia Plantarum," remarks, that "as nature never passes from one extreme to another, except by something between the two, so she is accustomed to produce creations of an intermediate and doubtful condition, which partake of both extremes, and so completely connect them, as to render it altogether uncertain to which they most belong."

This truth could hardly be appreciated by the naturalist who was conversant only with the natural productions of some small portion of the world, and it would be the more readily rejected by such a person, because, if true, it would obviously go to the annihilation of all definitions in natural history; for if every object is admitted to pass into some other object by an insensible gradation, it would be necessary to admit also that no real limits are to be found between one thing and another, and that absolute distinctions can have no existence.

But so many evidences of the truth of this theory are daily forcing themselves upon the mind of a naturalist to whom all the varied forms of species in different climates are submitted for examination, and who finds it, in a multitude of cases, so utterly impossible to frame any verbal or ideal definitions to which there shall be no exception, that he is constrained to recognize the doctrine of transition, at whatever inconvenience to the study of the science; not however applying it to species, for among them, as has already been shown, apparent transitions are chiefly accidental, but confining it to each and every combination above species, and inferior to classes. This is so true, that Linnæus is recorded to have confessed to one of his friends that he could not tell what constituted a genus; and Jussieu, in the preface to his "Genera Plantarum," declares that, as to a genus, there can be no certain definition of such a thing, nor any accurate directions given for the construction of it in

the natural system, *because species are collected together by their affinity in so imperceptible a web*, that the only meaning that is to be attached to a natural genus is, that it keeps together (prevents the separation of) species naturally related to each other, and does not interrupt the order of their arrangement.

A few common instances will illustrate this. A strawberry is apparently a very different genus from a Cinquefoil; yet if a species occurs with all the characters of Fragaria, but without the succulence of its receptacle, such a species becomes a Cinquefoil; this happens in Fragaria sterilis, now called Potentilla Fragaria. Amygdaleous plants are distinguished from Pomeæ by their solitary carpels and hydrocyanic acid; but some varieties of Prunus have several carpels, and Cotoneaster microphylla, a Pomeous plant, has hydrocyanic acid; in these instances there is a double transition. Nothing can well be more dissimilar than a Bean and an Almond tree, and both are types of certain natural groups: but Fabaceæ, to which the Bean belongs, exhibit so many gradations of structure, that at last they pass into a plant called Detarium, which has the drupaceous fruit and icosandrous stamens of Amygdaleæ; so that if an Amygdaleous plant should be discovered with pinnated leaves, there would no longer be a positive distinction between that group and Fabaceæ. In Lamiaceæ, the ovary is deeply divided into four lobes; in Verbenaceæ it is undivided. This, if permanent, would positively distinguish two natural groups in most respects much alike; and it really does form the only structural difference between them; but in Verbena itself the ovary is slightly lobed; Chloanthes, a Verbenaceous genus, has the habit of Lamiaceæ, and Hoslundia, a Lamiaceous genus, has the habit of Verbenaceæ.

To cases of this sort there is in fact no end. On this account some botanists have come to the conclusion that in characterizing the groups between the highest (classes) and the lowest assemblages (species), it is better to give up all attempts at definition, and to substitute brief descriptions of the *prevalent or typical characters*, considering all the minor groups as mere *tendencies* (*nixus*) towards this or that form of organization, the general nature of which is susceptible of description, but the precise nature of which is incapable of definition. Generic and ordinal characters are in this view mere expressions of certain ideas connected with structure; and plants will correspond with those ideas more or less in proportion as they approach the typical form in their organization. This view, which has been taken by Professor Lindley in his "Nixus Plantarum," and subsequent systematic works, is founded upon the theory well explained by Fries, that our conceptions of the nature of genera, orders, and similar collections of species, are most correctly expressed by a sphere, the centre of which represents typical organization, with rays (or deviations) proceeding from it on every side.

"Let us imagine," he says, "all nature to be an immense sphere, with rays converging in the *centre*, where they finally become confluent in a point, which may be called the point of *identity*. This point comprehends the perfection of all the rays; for that the most perfect and most completely formed creations, as the sun, are always situated in the centre, is testified by all authority, by all experience. The powers of nature, diverging from each centre in polar opposition, are continually passing into opposite series. A new sphere is formed by each opposition, whence the highest (most perfect) sphere is again and again resolved into new spheres, which form wholes of themselves, and each of which, according as its power is a more or less perfect evolution, in itself represents the whole in a more or less distinct degree. The centres of these spheres may be exceedingly distant from each other, but their rays always impinge upon the rays of some other sphere: hence those which run into each other are not the most perfect forms (*summa*) of each section, but the least perfect (*infima*)."

The imaginary points where the supposed rays cross each other are the stations of transitions of whatever kind; and supposing the spherical theory to be admissible, transition cases must necessarily exist in all directions.

This speculation is at variance with a more common one, that all organic beings are created in an ascending or descending series of developement; that, for instance, starting from man, the most perfect of all animals, an uninterrupted series of forms will be discovered down to mere microscopic animalcules; or

that between a forest tree and vesicular confervæ there exists an uninterrupted chain of beings, connecting the one with the other by insensible transitions. Bats, it has been said, form the transition from mammalia to birds, web-footed birds pass to reptiles, sponges combine polypes with vegetables, and the theory has been pushed so far as to assert, that the diamond forms the passage from the vegetable to the mineral kingdom. This speculation will probably find few advocates at the present day, so entirely is it opposed to facts, if taken in the form in which it was originally propounded; but if it is modified so far as to apply not to one series but to many series, it then at once explains and sustains the theory of Fries, whose observations upon this subject deserve to be quoted.

"All natural bodies originate in successive developement, yet in a continuous series within a determinate sphere. Every new sphere originates in a digression from a series which is otherwise continuous. Whenever a more perfect sphere is separated from one which preceded it, and has acquired a higher station than its parent, it may be itself pressed down by such new ones as emerge from itself; but the depressed sphere is also capable of continuation in its descent; and under this mode of developement the same principles and the same types are regenerated under more perfect forms in the higher spheres."

"Those, therefore, are mistaken who assume that nature proceeded in a simple series to her most perfect productions. Thus, for example, all parasites, both animals and plants, must necessarily have been created later than their matrix (and should therefore be the most perfect parts of the creation). But Fungi, which are the latest in the series of vegetable developement, are the most simple of all in their structure. As the evolution of the animal and vegetable kingdom may be said to have proceeded with nearly equal paces, so the different sections of vegetables cannot be said to have arisen out of a simple series, but out of parallel or radiant series. Many Algæ must have been created more recently than the most perfect plants, Entozoa than the most perfect animals."

Chapter VII.

Of the value to be assigned in Systematic Botany to the characters used in the construction of the assemblages intermediate between classes and species.

It will probably conduce to the practical application of the principles hitherto explained, if some statement is made of the general value of the characters that are most commonly employed in forming genera, orders, and other assemblages superior to species and below the classes. It is expected that, although this may be a very dry and uninteresting subject, it will be useful to a student who can have no experience to guide him in determining what points of structure are most or least essential in a given case.

The root, properly so called, offers no characters that have been found uniform in particular families; in fact, the modifications of which it is susceptible are so few, that it is difficult to conceive in what way they can be applied. Certain forms of root-like stems and buds have, however, been observed, to which some attention should be paid. In the first place, neither bulb nor rhizoma is known in Exogens, while in Endogens they are sometimes characteristic of particular orders. Thus, all Marantaceæ and Zingiberaceæ and most Iridaceæ have a rhizoma in one form or other, and bulbs are a usual character of Liliaceæ and Amaryllidaceæ; in the former, however, the bulb is often represented by a rhizoma, or cormus, as in Brodiæa, Leucocoryne and their allies, or by those succulent fibres called fasciculate roots, as in Asphodelus itself; and in the latter the bulb is sometimes entirely absorbed by succulent perennial roots, as in Clivia.

External variations in the figure of the stem are sometimes available as distinctions of orders. Thus, a twining stem is, almost without exception, found in Menispermaceæ, a square stem is universal in Lamiaceæ, and an angular one in Galiaceæ; but more frequently its figure affords no indication whatever of affinities.—Texture of the stem is of scarcely more value. Cactaceæ, it is true, have always the cellular tissue in excess; but even in this order, the Pereskias are scarcely more succulent than other plants; and Euphorbiaceæ and Asclepiadaceæ exhibit instances both of the most decided state of succu-

lence, and of the normal condition of stems in general.—In the internal arrangement of the layers of stems, not many modifications have been observed beyond those already noticed as distinguishing classes; nevertheless there are some that deserve serious attention. In Aristolochiaceæ there are no zones to the wood; in Piperaceæ and Nyctaginaceæ there is a structure almost intermediate between that of Exogens and Endogens, out of which Schultz has proposed to form a new class (*Natürliches System des Pflanzenreichs*); Passifloraceæ are exceedingly remarkable for having their woody system nearly cut into equal quarters; and Calycanthaceæ are known by the presence of four incomplete centres of vegetation surrounding the principal one, and so forming four angles which are visible externally. — (See *Mirbel's figure, in the Annales des Sciences,* vol. xiv. p. 367.)

The leaves are subject to modifications which, in determining the mutual relations of plants, are not less important than the functions which they perform in the vegetable economy. Their characters depend upon their relative position, their degree of division, their venation, and the presence or absence of pellucid dots within their substance. All Cinchonaceæ have opposite entire leaves; in Lamiaceæ, Apocynaceæ, Gentianaceæ, Monimiaceæ, and many others, they are also uniformly opposite; but in the genus Fuchsia, in which they are usually opposite, species exist in which they are not only alternate, but both the one and the other on the same plant; and alternate leaved species exist in Aggregosæ, Scrophulariaceæ, and Malpighiaceæ, the leaves of which are generally opposite. In Corylaceæ, Apiaceæ, Ternströmiaceæ, Hamamelaceæ, and Urticaceæ, they are uniformly alternate; but in Combretaceæ, Ericaceæ, and Fabaceæ, orders usually having alternate leaves, they are occasionally opposite. We hardly know how far this irregularity is connected with the following observations of Schlechtendahl, which, however, deserve attention. "Those leaves," he says, "which are connected either by their base, or by the intervention of a stipule, I call opposite; and those which are not so connected, spuriously opposite (pseudo-opposita). Opposite leaves are never disjoined (Cinchonaceæ and Silenaceæ); spuriously opposite ones, which are much more common, being easily disjoined, readily become alternate. Branches obey the same law as the leaves."—*Linnæa,* i. 207. Some Ranunculaceæ (Clematis) and many Asterales seem to offer exceptions to the statement. — All Spondiaceæ, Rhizobolaceæ, &c. have compound leaves; in many others they are always simple; and in such orders as Aceraceæ, Aurantiaceæ, Geraniaceæ, Rutaceæ, and Sapindaceæ, both simple and compound leaves are found. This character, therefore, is not considered of so much value as many others. Neither is the degree of division of the margin usually important, toothed and entire leaves being often found in the same order. Nevertheless there is no instance of toothed leaves in Cinchonaceæ, Gentianaceæ, Clusiaceæ, or Malpighiaceæ; and they are very rare in Endogenous plants.—Characters derived from the arrangement of veins are known to be in many cases of the utmost importance; and it is probable, that when this subject shall have been more accurately studied, they will be found of even more value than has been yet supposed. It is already known that the internal structure and peculiar growth of Exogens and Endogens are externally indicated by the arrangement of the veins of their leaves,—those of Exogens diverging abruptly from the midrib, and then branching and anastomozing in various ways, so as to form a reticulated plexus of veins of unequal size; while those of Endogens run straight from the base to the apex, or diverge gradually from the midrib, not ramifying in their course, but being simply connected with each other by transverse bars, examples of which are afforded, on the one hand, by the Rose, and on the other by the Iris and Arrow-root. Although a few exceptions exist to both these rules, yet the general characters of the leaves of those classes are such as we describe. But independently of this, many other orders are distinguished by modifications of venation. Thus, all Melastomaceæ have three or more collateral ribs connected by branched transverse bars, something in the way of Endogens; all Myrtaceæ have one or two fine veins running parallel with the margin, and just within it; most Corylaceæ have the principal lateral veins running straight out from the midrib to the margin; Betulaceæ are distinguished

by this among other characters from Salicaceæ; and the same peculiarity separates the genuine genera of Dilleniaceæ, called Delimeæ by De Candolle, from those of which Hibbertia is the representative. All Gentianaceæ, whose leaves are broad enough to have more veins than the central one, are rib-leaved.—Leaves which contain reservoirs of oily secretions, indicated by the presence of pellucid glands within their substance, are almost always universal in a given order. Thus, Myrtaceæ, properly so called, (with the exception of the paradoxical Pomegranate,) are distinguished by these glands from Melastomaceæ; in one genus of which, however, (Diplogenea,) slight traces of them are to be found: they are present in all Aurantiaceæ; by this character Winteraceæ are distinguished from Magnoliaceæ, Amyridaceæ from Connaraceæ, &c. &c. Samydaceæ are remarkable for their dots, being partly linear and partly round. In the orders Phytolacaceæ, Petiveraceæ, Lamiaceæ and Zygophylaceæ, there are, however, genera with and without pellucid dots. —The secretions of plants are rarely attended to in any other cases than those just mentioned, except when a milky fluid, generally indicating poisonous properties, is present; but to the presence or absence of the latter a good deal of importance is attached, perhaps not very correctly. Milk is characteristic of Papaveraceæ proper, of the Artocarpeous section of Urticaceæ, of Euphorbiaceæ, Apocynaceæ, and several other groups; but it also occurs in some Apiaceæ, and is not discoverable in those orders to which it is proper except at particular periods of the year. Some Acers (platanoides, macrophyllum and Negundo) milk; others (pseudo-platanus, &c.) do not milk. It has been said to be universally absent from Endogens, but it is abundant enough in the roots of Alisma Plantago, in Limnocharis, &c.

At the base of some leaves are frequently found little membranous or foliaceous appendages, called Stipules, which are in fact leaves in an imperfect state of developement. Their presence may therefore be understood to indicate a peculiar degree of composition in the leaves to which they belong, and they sometimes indicate affinities in a very remarkable manner. In studying them, however, care must be taken not to confound genuine foliaceous appendages, to which alone the name of stipules properly appertains, with dilatations, or membranous or glandular processes of the petiole, such as are found in Ranunculaceæ, Grossulaceæ, Apocynaceæ, Apiaceæ, and others. The presence of stipules is universal in Cinchonaceæ, which are thus distinguished from Galiaceæ, in Betulaceæ, Salicaceæ, Magnoliaceæ, and many others. The orders Cistaceæ, Saxifragaceæ, Loganiaceæ, and Rosaceæ, are among the few cases in which genera exist both with and without stipules.

The starved leaves found at the base of many flowers, and technically called Bracts, are rarely employed as distinctions of orders, offering scarcely any modifications of importance. In Brassicaceæ, however, they are never present, and in Marcgraviaceæ they are usually hollow, being folded together by their two edges, like the leaves of which carpels are formed.

Forms of Inflorescence are occasionally, but not often, found characteristic of particular tribes. Thus all Asteraceæ, Calyceraceæ and Dipsaceæ have their flowers in heads; all Apiaceæ bear umbels; all Plantaginaceæ, Cyperaceæ and Graminaceæ, have dense simple imbricated spikes; all Betulaceæ, Corylaceæ and Salicaceæ bear catkins; Pinaceæ have a strobilus or cone; and all Echiales have a gyrate inflorescence.

The calyx is used in a variety of ways to distinguish orders; but the characters it affords are far from being of equal or uniform importance. Its absence implies the absence of the corolla also, which cannot possibly be present when the calyx is away, unless, as in Compositæ, it is obliterated by the pressure of surrounding bodies. By its absence all the orders called Achlamydeous are characterized, such as Salicaceæ, Piperaceæ, Saururaceæ, &c.; but in Betulaceæ it is present in the male flowers, and in Euphorbia itself; among Polypetalous Dicotyledons it is wholly wanting. These exceptions do not, however, affect the general importance of characters derived from its presence or absence. If it is unaccompanied by the corolla, plants are said to be Monochlamydeous, and this is a point of pretty uniform value. We know of no true Monochlamydeous orders in which the presence of a corolla forms an exception, unless the faucial scales of Thymelaceæ are considered the rudi-

ments of a corolla.—The sepals or leaves of which it is composed are either distinct or combined; and from this circumstance, characters are sometimes advantageously derived. Thus in Scleranthaceæ and Silenaceæ the calyx is always monosepalous; in Frankeniaceæ it is constantly ribbed, &c.—The number of sepals is sometimes a character of importance, as in Brassicaceæ, in which they are always four, in Papaveraceæ, which have rarely more than two, and in the greater part of Endogenous plants, which have usually three. This character, however, requires to be used with circumspection, as there are more instances of the number of sepals being variable than regular. Thus in Linaceæ and Malvaceæ they are three, four, five; in Clusiaceæ, they vary from two to six; in Homaliaceæ, from five to fifteen; and in Samydaceæ, from three to seven.—The æstivation of the calyx is always to be well considered, as certain forms are often among the best known indications of affinity. Malvaceæ, Tiliaceæ, Elæocarpaceæ, Tremandraceæ, Sterculiaceæ, have it exclusively valvate among polypetalous dicotyledons with hypogynous stamens; Ternströmiaceæ and the rest of the calycose group of Exogens have the sepals constantly imbricated in a particular way; Vitaceæ have the lobes of the calyx distinct and wide apart from a very early period of their existence: but in Penæaceæ both valvate and imbricate æstivation exists.—In some plants the sepals are of equal size; in others they are very unequal either in form, direction, or texture; in the former case they are said to be regular, in the latter irregular, and by this difference certain orders are characterized. Thus Sapindaceæ and Polygalaceæ have a calyx constantly regular; but it frequently happens that both regular and irregular calyces co-exist in the same order, as in Rosaceæ, Lamiaceæ, Fabaceæ, and many others.—In most orders the sepals form one series only; others have them in two rows, and this has not been found to be connected with any material differences otherwise; but when the number of series is increased much beyond two, they cease to be separately distinguishable, and form an imbricated calyx, which is frequently confounded with the corolla, as in Calycanthaceæ. We know of no order in which genera with an imbricated calyx of this kind and a common calyx co-exist. It is one of the principal points which separate Calycanthaceæ from Rosaceæ.—The most important character connected with the calyx is, however, its cohesion or non-cohesion with the ovary; or, as botanists incorrectly call it, its being superior or inferior. Some orders are positively characterized by this, as Asteraceæ, Apiaceæ, Caprifoliaceæ, Orchidaceæ, and many more; and as it often happens that it exists without exception, it thus becomes a useful means of distinction. Scævolaceæ are, for instance, by this means at once known from Brunoniaceæ, and Cinchonaceæ from Apocynaceæ. No instance of a superior calyx has been found in Ranunculaceæ, Brassicaceæ, Papaveraceæ, Rutaceæ, and a number of others. But there are some singular exceptions to this rule. Thus, among Anonaceæ, an order with indefinite superior ovaries, we find Eupomatia, in which they are inferior; in Melastomaceæ all degrees of cohesion take place between the calyx and the ovary; and in Saxifragaceæ this uncertainty of structure is still more remarkable. It should, however, be observed, that in the two latter orders the tendency to cohesion between the calyx and the ovary may be almost ascertained by careful dissection; and even in Parnassia, an anomalous genus which is referred to Saxifragaceæ, usually having an ovary completely superior, there exists a species in which it is partially inferior. We have said that the difference between a superior and inferior calyx consists only in the cohesion of that organ with the ovary in the one case, and its separation from it in another; and this is the view which is always taken of it, all that part which intervenes between the segments and the pedicel being considered the tube of the calyx. But it is to be suspected that theory has carried botanists too far, and that there are cases in which the apparent origin of the calyx is the real origin. Upon this supposition, what is now called the tube of the calyx may be sometimes a peculiar extension or hollowing out of the apex of the pedicel, of which we see an example in Eschscholtzia, and of which Rosa and Calycanthus, and perhaps all supposed tubes without apparent veins, may also be instances. In this case the whole of our ideas about superior and inferior calyxes will require modification.

The second floral envelope, or the corolla, consists of a number of leaves equal

to those of the calyx, and alternating with them, in addition to which they are usually coloured. If the corolla is present, a plant is said to be Dichlamydeous, and much importance is attached to this peculiarity; more, we think, than it deserves. It separates plants having much natural affinity, as Euphorbiaceæ, far from Rhamnaceæ, Amarantaceæ widely from Illecebraceæ, and it is also one to which there are many exceptions. This is, however, not the case with monopetalous dicotyledons, Primulaceæ and Oleaceæ being almost the only instances of orders among those which are truly monopetalous, containing apetalous genera. The difference between a monopetalous and a polypetalous corolla is this, that in the one the leaves out of which the corolla is formed are distinct, and in the other united. Great value is attached to this, and it is in fact a difference of first-rate importance: thus, all Ranunculaceæ, Rosaceæ, Brassicaceæ, Lamiaceæ, Scrophulariaceæ, and Bignoniaceæ are equally, without exception, monopetalous: but in the polypetalous orders of Crassulaceæ, Rutaceæ, Polygalaceæ, Ternströmiaceæ, &c., there are monopetalous genera.—The æstivation of the corolla rarely furnishes characters connected with the natural properties of plants; nevertheless, Asteraceæ are essentially distinguished by their valvate, and Asclepiadaceæ and Apocynaceæ by their contorted æstivation, an exception to the one existing only in the genus Leptadenia, and to the other in Gardneria. The æstivation of both calyx and corolla has as yet received too little attention for its value to be judged of generally.—The regularity or irregularity of the corolla is most commonly important: thus, Orchidaceæ, Polygalaceæ, Bignoniaceæ, Fumariaceæ, are irregular without exception; the regular corolla of Braginaceæ will almost distinguish them from Lamiaceæ, which have frequently an irregular one; yet Echium in Boraginaceæ is irregular, and Caprifoliaceæ exhibit all the gradations from a corolla of the most irregular form to one of the most perfect symmetry. In Asterales both are found continually in the same; in Lobeliaceæ, which may be almost always distinguished from Campanulaceæ by their irregularity, become nearly regular in Isotoma.—The venation of the petals is scarcely ever employed for distinction, little being at present known of it. Asterales are distinguished by the peculiar arrangement of the veins of their corolla; and they are always oblique in Hypericaceæ.

From within the corolla arise the Sexes. From the manner in which these are composed, good characters may sometimes be derived, but more frequently no characters at all. Thus, Xanthoxylaceæ are known from Rutaceæ by their unisexual flowers; all Euphorbiaceæ, Begoniaceæ, Pinaceæ, Myricaceæ, are unisexual. But Vitaceæ, Graminaceæ, Cyperaceæ, Chenopodiaceæ, Apiaceæ, and even Ranunculaceæ, contain hermaphrodite and diclinous genera; and it is familiar to every one, that flowers of all these kinds (that is, male, female, and hermaphrodite) stand side by side in Asterales.

The stamens either arise immediately from below the ovary, having no adhesion to the calyx, when they are said to be hypogynous, or they contract an adhesion of greater or smaller extent with either the calyx or corolla, when they become perigynous, or, finally, they appear to proceed from the apex of an inferior ovary, in which case they are named epigynous; but it is usually now understood that all stamens take their origin from below the ovary; and if this opinion be well founded, there will be no material difference between those which are perigynous and those which are epigynous; and these two modifications are accordingly confounded together by most modern botanists. A. Brongniart, however, conceives epigynous stamens to be essentially distinct from perigynous, founding his opinion upon the genus Raspailia, which has a superior ovary, from the top of which arise the stamens; but it is possible perhaps to explain this apparent anomaly. To the difference between perigynous and hypogynous stamens the French school attaches the greatest value, not being willing to admit any genus with hypogynous stamens into an order with perigynous ones, and *vice versâ;* and there is somewhere an observation, that of such primary importance is this distinction, that while poisonous orders are to be known by their stamens being hypogynous, all in which they are perigynous are wholesome. Setting aside, however, this hypothesis, which has not the general application that has been ascribed to it, there is no doubt that insertion of stamens does very often go

along with essential differences of other kinds; for example, it distinguishes with precision Rosaceæ from Ranunculaceæ, Violaceæ from Passifloraceæ, Reaumuriaceæ from Nitrariaceæ, Aurantiaceæ from Burseraceæ. But on the other hand, there is not only frequently, as may well be supposed, so slight a degree of adhesion between the stamens and calyx as to render it difficult to say whether the former are perigynous or hypogynous, as in Tamaricaceæ, and many others; but there are orders which do really exhibit instances of both modes. Thus Eschscholtzia has decidedly perigynous stamens, and yet it is a genus of Papaveraceæ, the character of which is to have them hypogynous; and all kinds of gradations, from the one form to the other, are observable in Saxifragaceæ. The stamens of Macrostylis, among the hypogynous order Rutaceæ, are manifestly perigynous. In Geraniaceæ, the genus Geranium has the stamens hypogynous, and Pelargonium perigynous. Alsinaceæ are arranged among genera with hypogynous stamens, yet some of them (Larbrea and Adenarium) are perigynous; in Illecebraceæ, part of the genera are perigynous, and part hypogynous. — The manner in which the stamens cohere is sometimes an indication of affinity; for instance, they are monadelphous in Malvaceæ and Meliaceæ, diadelphous in great numbers of Fabaceæ, polyadelphous in Hypericaceæ; but more commonly this character is unimportant, as in Malvaceæ themselves, which have sometimes distinct stamens; Fabaceæ, which have very often such; and Ternströmiaceæ, which have both united and disunited ones.—It not unfrequently occurs, that the conversion of the petals into stamens takes place imperfectly, in which case a part of the stamens is said to be sterile, and this is sometimes a useful character for detecting affinities. Thus, in many Buttnerieæ, one-fifth are sterile and petaloid, in Francoaceæ every other one, in Aquilariaceæ two-thirds, in Bignoniaceæ the uppermost of five is rudimentary.—A peculiarity of a similar nature is the want of symmetry which sometimes exists between the petals or sepals, and stamens. Supposing the flower to be formed without abortion of any kind, and by regular alternation of metamorphoses, as is usually the case, the petals will be always some multiple of the sepals, and the stamens of the petals; and of course any irregularity in this respect will destroy the supposed symmetry. This is often a point of much importance to observe; for example, in Boraginaceæ, the stamens are always equal to the segments of the corolla, and the flowers of that order are consequently symmetrical; in Lamiaceæ, on the contrary, one at least of the stamens is constantly missing, and the flowers are therefore regularly unsymmetrical, a character by which these orders may be constantly known, when the form of their corolla will not distinguish them. In Phytolaccaceæ there is a constant tendency to a want of symmetry; and this is one of the characters by which that order is known from Chenopodiaceæ.

That part of the stamen which contains the fertilizing matter of the anther, is a case usually consisting of two parallel or slightly diverging cells, containing pollen, and opening by a longitudinal fissure; but from this plan many deviations take place, which are of value in determining affinities. Thus, all Malvaceæ, properly so called, and Epacridaceæ, have but one cell; in Lauraceæ and Berberaceæ, the valves are hinged by their upper margin; in Ericaceæ the pollen is emitted by pores; in Melastomaceæ the same takes place, along with a peculiar conformation of the lower part of the anther; in Hamamelaceæ, dehiscence is effected by the falling off of the face of the anthers; but in Solanaceæ, the genera of which have usually their anthers bursting longitudinally, the genus Solanum itself opens by pores.—The mode in which the anther is united with the filament is sometimes taken into account, as in Anonaceæ, Nymphæaceæ, Humiriaceæ, and Araceæ, or Typhaceæ, in which they are always adnate; and Graminaceæ, in which they are as regularly versatile. But this modification appears of no great moment, nor indeed does any peculiarity of the connective, all kinds of forms of which are found in Lamiaceæ; and even in the small order of Penæaceæ we have anthers with the connective both excessively fleshy, and in the ordinary state.

Pollen rarely affords any marks by which affinities are to be traced. The most remarkable deviations from its usual nature exist in Asclepiadaceæ and Orchidaceæ; the former having it always in a state of concretion, resem-

bling wax, by which they are known from Apocynaceæ, and the latter having it frequently so, but also containing numerous genera, the pollen of which is scarcely distinguishable from its ordinary powdery state.

Immediately between the stamens and the ovary is sometimes found a fleshy ring or fleshy glands, called a Disk, and supposed for very good reasons to represent an inner row of imperfectly developed stamens. The presence of this disk is constant in Apiaceæ, Asterales, Lamiaceæ, Boraginaceæ, and Rosaceæ, while its absence is equally universal in others. It is not, however, much used as a principal mark of distinction, its real value not having been yet ascertained. There are some curious modifications of it in Rhamnaceæ and Meliaceæ. It is a remarkable fact, that in Gentianaceæ and their allies, which have the pericarpial leaves right and left with respect to the common axis of inflorescence, it is never truly present; while in Scrophulariaceæ and their allies, the pericarpial leaves of which are anterior and posterior, it is generally present in one shape or other.

The last modification of leaves in the fructification consists in their conversion into what is called the female organ, or ovary; that is to say into the case which contains the young seeds or ovules. Now that the structure of this part is well understood, we know that an ovary either consists of one or several connected pericarpial leaves, called carpels, arranged around a common axis, or of several combined into a single body. Upon this difference the distinction depends of what are called apocarpous ovaries, or those of which the carpels are distinct; and syncarpous, or those of which the carpels are compactly combined. These differences appear of much importance, and subject to as few exceptions as any modifications that botanists make use of. Thus Berberaceæ are distinguished from Papaveraceæ, Nelumbiaceæ from Nymphæaceæ, Amaryllidaceæ from Burseraceæ, Boraginaceæ from Ehretiaceæ, and the like. But at the same time it will be seen, that cases exist of both forms being found in the same natural order, as Xanthoxylaceæ. This, however, is rare.—The cohesion of the ovary with the calyx, or its separation from it, has been already treated of in speaking of the calyx.—An ovary may be either one-celled, in consequence of its consisting of a single carpel, in which case it will belong to the apocarpous division; or it may consist of several carpels strictly cohering, and therefore syncarpous, but nevertheless one-celled, in consequence of the obliteration of the dissepiment. Peculiarities of this latter nature are almost always of ordinal importance, *at least if the placentæ are parietal;* for instance, the latter is the structure of Papaveraceæ, Homaliaceæ, Flacourtiaceæ, Cucurbitaceæ, Papayaceæ, and Violaceæ, to which there is no exception; but Alsinaceæ and Bruniaceæ, the usual structure of which is to be one-celled, have the placentæ in the centre; and in both these orders there are genera, the ovary of which contains several cells.—Another point that deserves particular attention is the relation borne to the axis of inflorescence by the pericarpial leaves, of which an ovary is formed. What the exact value of this character may be is not yet known; but it seems that Gentianaceæ and their allies have their pericarpial leaves right and left of the axis, while Scrophulariaceæ and their allies have the pericarpial leaves anterior and posterior, with respect to the axis. Rosaceæ and Fabaceæ differ in a nearly similar way.—Connected with the apocarpous or syncarpous state of the ovary is the union or separation of the styles, which therefore scarcely require distinct mention. It is as well, however, to remark, that the separation of styles is commonly a sign of the apocarpous state of the ovary, provided the latter is not very apparent otherwise; and the cohesion of the styles is constantly an evidence of the contrary; and in this view the Elder and Hydrangea may be justifiably separated from Caprifoliaceæ.—The receptacle or growing point round which the carpels are disposed is commonly so minute as to interpose but little matter between the bases of the carpels which stand nearly parallel with each other. But this part occasionally takes on an extraordinary developement, becoming fleshy, and either separating the carpels entirely from each other, as in the Strawberry and in Ochna, or causing them to diverge at their base, to which they adhere by the points of their ovary. The term *gynobase* has been invented by the French to denote this kind of receptacle, and strictly speaking it

ought to be applied to all cases of an enlarged receptacle. But in practice nothing is considered a gynobase, on which more than one row of carpels is arranged. This character, indicated in the fruit by the presence of a central woody column to which the carpels partially adhere, is sometimes of so much value as to form the cementing character of several well-marked and very distinct orders. It has given rise to a group called Gynobaseosæ among Polypetalous Exogens.

The stigma seldom offers any good characters. In some cases, however, advantage is taken of it, as in Linaceæ, the capitate stigmas of which distinguish them from Alsinaceæ, where they occupy the whole inner face of the styles; and in Goodeniaceæ, Scævolaceæ, and Brunoniaceæ, there is a peculiar membranous appendage enveloping the stigma, and called an indusium, which distinguishes those orders from all others.

The number of the ovules (that is to say, whether they are definite or indefinite) is frequently an important difference, as, for example, between Campanulaceæ and Asterales, Goodeniacæ and Scævolaceæ; but while considerable value usually attaches to this, it must not be forgotten that there are exceptions to it in several instances, especially in Caprifoliaceæ, Fumarieæ, and Brassicaceæ.—The position of the ovules is much more essential than their number, and may be considered as one of the most valuable forms of structure that can be taken into account. It is uniform in Asterales, Valerianaceæ, Apiaceæ, and others; but in Sanguisorbeæ, Pedaliaceæ, and Styraceæ, both erect and suspended ovules co-exist; this union of the two positions occurs in a more remarkable degree in Penæaceæ; and among Violaceæ, the genus Conohoria offers, according to A. St. Hilaire, *Pl. Usuelles*, No. 10, an instance of three kinds of direction in as many species; in C. Lobolobo, the ovules are ascending; in C. castaneæfolia, they are suspended; and in C. Rinorea, one is suspended, one ascending, and the intermediate peritropal, or at right angles with the placenta.—The situation of the foramen of the ovule is a circumstance that should always be taken into account, because it indicates with certainty the future position of the radicle, which it is of importance to ascertain, but which will be more properly spoken of in considering the value of distinctions drawn from that source.

The ripened ovary is the fruit. The differences in its structure are of the same nature as those of the ovary, and need not be repeated. Its texture and mode of dehiscence are the principal sources of distinction, but they perhaps deserve as little attention as any of which botanists make use. It is true that the fruit of all Grossulaceæ is baccate, of all Lamiaceæ indehiscent, and of all Primulaceæ capsular; but Marcgraaviaceæ, Melastomaceæ, Myrtaceæ, Ranunculaceæ, and Rosaceæ, with a crowd of other orders, contain both baccate and capsular, dehiscent and indehiscent genera.

The characters obtained from the position of the seed are of the same value as those from the position of the ovule; in addition to which, the peculiarities of the testa are made use of. —In some Monocotyledonous orders, as Liliaceæ and Smilaceæ, the texture has been employed as a mark of distinction, but with little reason, the soft thin testa of Smilax being found in genuine Liliaceæ of the Asphodeleous section; it is indeed rather surprising that botanists should have ever thought of having recourse to a distinction so wholly unconnected with function or typical organization.—The seed being winged or otherwise, distinguishes Meliaceæ from Cedrelaceæ, and the presence of a fungous swelling about the hilum is a good characteristic of Polygalaceæ.

The substance that surrounds the embryo is the Albumen; its absence or presence constitutes a valuable mark of distinction. There can be no doubt that when it exceeds the bulk of the embryo very considerably, as in Ranunculaceæ, Papaveraceæ, Apiaceæ, Grasses, and the like, it is of such importance, that no plant destitute of albumen is likely to be found appertaining to such orders, for in such cases it is to be supposed that it contributes essentially to the nutrition of the embryo when first germinating; and is in reality indispensable to it. But on the other hand, it is much to be doubted whether its presence or absence deserves much attention in orders which are called by German botanists subalbuminous, where it is a mere residuum,—that is to say, where the embryo and albumen are of nearly

equal bulk; for it should be remembered, that it always exists in seeds at some period of their existence, and that its remains may very well be expected to be found in almost any seeds; thus, in fact, both albuminous and exalbuminous seeds are found in Proteaceæ (Brown in *Linn. Trans.* x. 36); even in Rosaceæ, which are as free from remains of albumen as any order, it is said to be distinctly present in Neillia, and in other orders traces of it are to be seen adhering to the inner membrane of the testa.—The texture of the albumen is frequently consulted with advantage; in all Cinchonaceæ it is horny or fleshy; Euphorbiaceæ, oily; Grasses, Polygonaceæ, Chenopodiaceæ, mealy; in Anonaceæ, it is ruminated, &c.; but among Apocynaceæ, which have solid albumen, it is ruminated in Alyxia.

The direction of the Embryo within the testa, which is indicated in the ovule by the foramen, is one of the very few characters to which we know of no exceptions; and if it were a less obscure point of structure, it would be consequently one of the most useful. For example, in all Cistaceæ, Urticaceæ, and Polygonaceæ, the radicle is not turned towards the hilum, as in other tribes, but takes an opposite direction; and these orders are distinguished from their allies by this, better than by any other known character.

The number of Cotyledons is one of the means of distinguishing the great natural divisions called Monocotyledons, Dicotyledons, and Acotyledons. There are, however, plants among Monocotyledons with two cotyledons, as the common Wheat; and among Dicotyledons with only one, as Penæa and some Myrtaceæ; or even none, as Cuscuta and Utricularia; or several, as Schizopetalon in Brassicaceæ, Amsinckia in Boraginaceæ, Ceratophylleæ, and most Pinaceæ.—The position of the embryo with respect to the albumen is of variable importance; in all Grasses it is lateral, in Cyperaceæ it is enclosed within the base of the albumen, and thus it furnishes an absolute distinction between those two important orders. But among Polygonaceæ, Rheum has it in the centre of its albumen, and Rumex on one side.—Differences in the manner in which the embryo is folded up are always of great consequence; because, although they may vary in particular natural orders, yet they are in such cases characteristic of subordinate divisions in the orders. For instance, both a straight embryo and one with the radicle bent down upon the cotyledons occur in Fabaceæ; but the first marks the Papilionaceous division, and the last the two groups of Cæsalpinieæ and Mimoseæ. Brassicaceæ, Capparidaceæ, Resedaceæ, Menispermaceæ, &c. have a curved embryo; Malvaceæ and Convolvulaceæ a crumpled one; but in Silenaceæ we have both a straight and annular one, and in Chenopodiaceæ and others equal uncertainty exists.

The only remaining character of vegetation which it is necessary to notice is a singular and very uncommon one, which distinguishes a few small families of plants. This consists in the presence of the remains of the Amnios around the embryo in its perfect state: the Amnios always surrounds the embryo in an early state, but is most commonly absorbed before the formation of the embryo is completed; but in Saururaceæ, Piperaceæ, and Nymphæaceæ, it remains around the embryo in the form of a sac, which was mistaken by Richard, who did not understand its nature, for a peculiar appendage of the embryo, or rather for a particular form of the radicle.

Chapter VIII.

Of the practical application of the foregoing principles.

If the foregoing principles have been rightly understood, their application will lead to the formation of a Natural arrangement of all known plants; by which we must be understood to mean an arrangement wherein all the groups will consist of species more nearly related to each other than to any thing else; where every genus, alliance, group, &c. will consist of species, &c., in the closest affinity with each other.

If it could be shown that in all cases of affinity one character would be stronger than all others, another result would be that there could be but one Natural System, and that, however long botanists might be in discovering it, they must at last and inevitably arrive at *the* one system and no other; and this proposition is actually maintained by some naturalists. But there are probably no cases in which there is a preponderating affinity in one direction and

one only: on the contrary, the equal affinities of plants are numerous and complicated, and in many respects it is impossible to demonstrate what their relative value really is; consequently, instead of one certain and inevitable result, instead of one fixed and immutable system to which the application of certain admitted principles must of necessity lead, several systems have been and may still be devised, all of which are natural and yet all different: not, however, different in their great leading features, but in their subordinate details. The great leading features of a system consist in the orders or first groups of genera, and in the classes or last groups of orders. About these there can be only one opinion, whenever all the data requisite for certainty shall have been collected; whatever differences in opinion concerning them may now exist, arise from the absence of many important data. But as to the arrangement of the genera in the orders, or of the orders in the classes, that always has been and ever will be a matter about which opinion will vary according as new facts are made known, or as persons take different views of the same facts. However wrong, therefore, Fries may be in asserting that there is no such thing as an artificial system, he is not far wrong in asserting that there is no absolutely natural system, because all systems, as far as their arrangement is concerned, are necessarily artificial; and a system which to-day is called Natural, may to-morrow become, by the accession of new ideas, artificial; as that of Tournefort, &c.

Nevertheless, it is very possible that particular modes of arrangement may be less natural than others; that is to say, may be less calculated to keep together corresponding assemblages; and that others may be perfectly natural in their classes and orders, but purely artificial in their intermediate details. Thus, Jussieu, in employing the single and absolute character of hypogynous, perigynous, and epigynous insertion of the stamens, rendered all his system artificial except the classes and orders; and De Candolle, in adhering to the same principle, destroyed in a great degree the value of what he calls his cohorts.

It may be, and indeed has been urged, that as a lineal arrangement is the only one that can be adopted in books, and as this is altogether incapable of indicating the nature of a system which "has for its very aim to interweave all the objects of nature in a close and compact web of mutual dependence," so it is really of little importance whether the intermediate grouping of plants is more or less artificial, as it must necessarily be so in some degree. But this we think is a great and very important mistake. It surely does not follow that because our finite means are incapable of explaining altogether what is infinite, that therefore we should not make the best use of the means of explanation that we actually possess; and yet this is the same thing as to say that, because a part of the most natural arrangement must necessarily be in some measure artificial, it does not matter how artificial it all is. It might as well be said, that because additions to the amount of our knowledge of species are daily accruing, and because so long as these additions are taking place our ideas of systematic arrangements will be changing, therefore it is not worth occupying ourselves with systematic arrangements at all, until every existing species has become correctly known. To admit such doctrine as this would be to give up the search for perfection in any thing; no one can hope to attain perfection; and there can be no reasonable doubt, that new points of view and continual improvements of what has gone before will be occurring to those who shall live a thousand years hence.

The true method of proceeding, with regard to the principles treated of in previous chapters, is to arrange the assemblages intermediate between the highest and lowest combinations in a manner *as little artificial as existing circumstances will allow.*

So little, however, has this been attended to, that in speaking of the Natural System of Botany as a whole, we shall be obliged to pass by the plans of Jussieu and De Candolle, and to take for the basis of the observations in the succeeding chapter, some one of those recent systems, which, although founded upon the writings of those two distinguished botanists, in the same manner as theirs are upon the discoveries and improvements of Ray and Tournefort, differ from them essentially in the arrangement of what we have designated as the intermediate assemblages. We are the more induced to take this course, because we have no space in this essay to notice all the plans that have been

proposed for a Natural System. Partly for a similar reason, and secondly because it is the most recent, we select for the text of the succeeding chapter the system of Professor Lindley, imperfect as he admits it to be, and great as are the changes and improvements that he feels it must require before it can be at all established.

Chapter IX.

Of Natural Systems.

A Natural System is a classification of species according to their respective affinities, so that those shall be placed next each other which correspond in the greatest number of particulars, and those be stationed most remotely that have the fewest points of agreement. It is not in our power to put this idea into practice altogether; we are therefore obliged to add, that those also are Natural Systems in which the principle is recognized as essential and fundamental.

In classifying either the vegetable or animal kingdoms, two diametrically opposite methods may be pursued, both of which shall be strictly natural. We may either proceed from the most imperfect forms of organization, or correctly speaking the most simple, for every thing is equally perfect after its kind, to the most complicated; or from the most complicated to the most simple. The first is the course pursued by Jussieu; the latter is that of Ray and De Candolle. It may at first sight appear to be of little moment which of these methods is pursued; but we agree with Fries and De Candolle, that in reality there is a material difference between these plans. "To me," the former says, "it appears most advisable to commence with that which is most perfect, most completely developed, and therefore most easily understood; and thence to descend to forms of a more imperfect kind, and therefore of a more doubtful nature. The half-developed portions of the lower forms of the creation would never be understood, if they were not more completely developed in the higher forms. This is the path which is pointed out both by experience and common sense; the idea of a seed is not derived from an Uredo, nor that of a vegetable from an Erineum; but the reverse. This is especially true of those lower spheres which bring up the rear: the last point of simplicity will never be attained, and will never be determined; although our microscopes are daily extending our views, the poles of vitality will never be reached. It is better, therefore, to set out from a *certain* point (the centre) than from an *uncertain* point (the circumference), which may be extended to infinity. So it is more wise, in studying Man, to take our notions of humanity from those in whom it exists in the highest degree of perfection, rather than to search overcuriously for those whose intellect is approximating to that of animals."

To this it may be added, that we really know much less of simple than of complicated forms, and it is contrary to all the rules of logic to begin by objects that are little known in order to understand those which are better known. We should form an odd notion of a man from a monad, but we should be able to understand a monad from our knowledge of a man.

Taking then this method of commencing our inquiry—we find that the most complete cases of structure that can be discovered are those where, in addition to stems and leaves wherewith to grow, and seed by which to multiply, there is a peculiar and complicated sexual apparatus of stamens and pistils by the action of which the seeds are fertilized. These, the most perfect forms of plants, have also other characters in common, all of which indicate a higher grade of organization; they have flowers; they are anatomically composed of cellular tissue and spiral vessels, and the seeds which they produce have two definite points of growth, of which one becomes invariably a stem, and the other a root. Those plants, on the contrary, which have no sexual apparatus, are also destitute of flowers; they have no true spiral vessels in their anatomical structure, but grow chiefly by aid of their cellular tissue, and the seeds which they produce have no definite points of growth, but produce stem or root indifferently from any point of their surface; their seed is therefore different from true seed, and is called a spore or sporule. This first examination shows then that we have two sorts of plants differing essentially in the degree of their developement, in the manner in which they are multiplied, in the means by which their vital actions are performed, and consequently in their whole mode of existence. These may be provisionally set down thus:—

Sexual. — Flowering. — Vascular. — Seminiferous.

Asexual. — Flowerless.—Cellular.—Sporiferous.

Viewed in another way, namely, with reference to their manner of growth, plants again divide into two wholly different series; in one of which the trunk every year after its first formation either actually increases in diameter or adds new matter to its solid contents; and this series comprehends two parallel and essentially dissimilar types, in which one adds its new matter to the outside of its wood near the circumference of the stem, and the other to the inside of its wood near the centre; the first are EXOGENS, the latter ENDOGENS. In the other series the stem, when once formed, neither increases in diameter nor adds new matter to its solid contents; but merely lengthens at its extremity; such plants are ACROGENS. This is another set of fundamental peculiarities which will necessarily regulate some of the most important vital actions of the species comprehended under them. Upon comparing these series with the first class of peculiarities, it appears that Exogens and Endogens are uniformly Sexual, &c.; and that Acrogens are as uniformly Asexual; hence we have three great fundamental groups instead of two—namely,

1. Sexual. — Flowering. — Vascular. —Seminiferous.—Exogens.

2. Sexual. — Flowering. — Vascular. —Seminiferous.—Endogens.

3. Asexual.—Flowerless. — Cellular. —Sporiferous.—Acrogens.

Each of these three groups has other peculiarities, which mark it in one way or another. Exogens have an embryo with two cotyledons (Dicotyledons); in germination, their young root springs directly from the apex of the radicle (Exorhizal); their leaves have netted veins, if any; the parts of their flowers are usually arranged upon a quinary or quaternary plan. Endogens have an embryo with one cotyledon (Monocotyledons); in germination, their young root springs from within the point of the radicle (Endorhizal); their leaves have simple parallel veins, if any; the parts of their flower are usually arranged upon a ternary plan. Acrogens have no embryo, and consequently no cotyledons (Acotyledons); in germination, their young root springs from any part of the spore (Heterorhizal); their leaves have forked veins, if any; flowers they have none. These various circumstances place the distinctions between the three fundamental classes in a still stronger light; and serve to show that when plants differ in one very essential character, they also differ in others, the number of which will be in proportion to the importance of the first character. If we again combine all these equivalent and corresponding characters in a rather different manner, they will finally offer the following contrast.

Exogens, or Dicotyledons,	have sexes, spiral vessels, seeds, 4-5-nary flowers, netted-veined leaves, exorhizal germination.
Endogens, or Monocotyledons	have sexes, spiral vessels, seeds, 3-nary flowers, parallel-veined leaves, endorhizal germination.
Acrogens, or Acotyledons,	have no sexes, no spiral vessels, spores, no flowers, forked veined leaves, heterorhizal germination.

These distinctions speak so directly to our senses, that no person when he has once understood them would be at all likely to call them in doubt. To know that the forest trees and bushes, and the common herbs of the field, are Exogens; that Palms, and Lilies, and Rushes, and Grasses, are Endogens; and that Acrogens answer to Ferns and Mosses, and Lichens and Fungi, is quite sufficient to impress the mind with a general, if not a very distinct perception, that while these groups called classes are totally different from each other, they have great and obvious marks of correspondence among themselves.

There are many who believe that these are the only classes into which the vegetable kingdom is capable of being divided. But others add two more. From Exogens are struck off those curious plants which, having sexes, nevertheless have them in a singularly incomplete state; their young ovules being fertilized by direct contact with the pollen, instead of through the intervention of a style and stigma; in these plants, moreover, the vascular system is more imperfect than in other Exogens, and their leaves, if veined, have either the forked veins of Acrogens, or the parallel veins of Endogens. They may therefore be reasonably

looked upon as a fourth class, and are called GYMNOSPERMS.

Finally there are certain plants which, to an appearance like that of Fungi, and an almost total absence of spiral vessels, add the flowers of Endogens, and the spores of Acrogens, have sexes, and the result of their sexuality is not an embryo, but a homogeneous reproductive body, with neither radicle nor cotyledons. They are supposed to be, in all cases, parasitical on roots, and hence have gained the name of RHIZANTHS; they constitute a fifth class.

These five classes, viz.,

1. Exogens,
2. Gymnosperms,
3. Endogens,
4. Rhizanths,
5. Acrogens,

are admitted by Professor Lindley. Subordinate to them are numerous groups, each divided into alliances, under which the orders are finally arranged.

Of the genera we can of course give no account in a short treatise like this; but such an abstract as the following, of the characters of the higher combinations, is necessary, to render the foregoing discussion either useful or intelligible. For a full explanation of the more special reasons upon which the system is founded, the reader is referred to the work itself from which these characters are abridged.*

* A Natural System of Botany; or a Systematic View of the Organization, Natural Affinities, and Geographical Distribution of the Vegetable Kingdom. By John Lindley, Ph. D. &c., Second Edition. London. 1836.

THE NATURAL ORDERS OF PLANTS.

Class I.—EXOGENS OR DICOTYLEDONS.

Elementary organs consisting of both cellular and vascular tissue, a portion of the latter being elastic spiral vessels. Trunk increasing by an annual deposit of new wood and cortical matter between the wood and bark. Leaves articulated with the stem, their veins reticulated. Propagation effected by stamens and pistils. Ovules in a pericarp, embryo with two or more opposite cotyledons.

Sub-class I.—POLYPETALÆ.

Floral envelopes consisting of both calyx and corolla; the latter composed of distinct petals.

Group 1.—Albuminosæ

The albumen very considerably larger than the embryo, and forming the great mass of seed.

Alliance 1.—Ranales. *Herbaceous, rarely woody, plants; either with the carpels more or less distinct, or if that is not the case, with parietal placentæ.*

Order 1.—*Ranunculaceæ.* Sepals 3-6, deciduous. Petals 3-15. Stamens hypogynous, anthers adnate. Carpels numerous, or united into a single pistil. Seeds either erect or pendulous. Herbs or shrubs. Leaves with the petiole dilated.

Sub-order Podophylleæ. Sepals 3. Petals in two or three rows. Stamens hypogynous; anthers linear or oval. Torus not enlarged. Fruit 1-celled. Seeds sometimes having an aril. Herbaceous plants. Leaves lobed.

Order 2.—*Papaveraceæ.* Sepals 2. Petals either 4 or some multiple of that number. Stamens hypogynous, generally numerous. Fruit 1-celled with parietal placentæ. Seeds numerous. Herbaceous plants or shrubs with a milky juice. Leaves alternate.

Sub-order—Fumarieæ. Sepals 2. Petals 4; parallel; the outer one or both saccate at the base. Stamens 6, in 2 parcels. Herbaceous plants with brittle stems and a watery juice.

Order 3.—*Nymphæaceæ.* Sepals and petals imbricated, passing gradually into each other. Stamens numerous, inserted above the petals into the disk; filaments petaloid; disk large, fleshy. Fruit many-celled. Seeds very numerous, attached to spongy dissepiments. Embryo on the outside of the base of the

albumen, in a bag. Herbs with peltate or cordate fleshy leaves, growing in quiet water.

Sub-order—Hydropeltideæ. Sepals 3 or 4. Petals 3 or 4. Stamens definite or indefinite. Ovaries 2 or more; fruit indehiscent. Seeds definite. Aquatic plants with floating leaves.

Order 4.—*Nelumbiaceæ.* Sepals 4 or 5. Petals numerous. Stamens numerous. Disk fleshy, enclosing in hollows of its substance the ovaries, which are monospermous. Nuts numerous, half buried in the disk. Herbs with peltate, floating leaves.

Alliance 2.—Anonales. *Woody plants in all cases, often trees with the fruit composed of distinct carpels, which occasionally grow together into a solid mass. The valves of the anthers separating by a perpendicular line.*

Order 5.—*Cephalotaceæ.* Calyx coloured, six parted, with a valvate æstivation. Corolla 0. Stamens 12. Carpels 6, one-seeded; ovule erect. A stemless herb with operculate pitchers. Flowers small.

Order 6.—*Myristicaceæ.* Flowers unisexual. Calyx trifid. Ovary superior, with a single erect ovule. Fruit 2-valved. Seed enveloped in a many-parted aril; albumen ruminate. Tropical trees, often yielding a red juice.

Order 7.—*Magnoliaceæ.* Sepals 3-6. Petals 3-27. Stamens indefinite. Carpels numerous, distinct or consolidated. Trees or shrubs with convolute stipules. Flowers large, solitary.

Order 8.—*Winteraceæ.* Sepals 2-6. Petals 2-30. Stamens hypogynous. Ovaries 1-celled with suspended or erect ovules. Fruit consisting of a single row of carpels. Seeds with or without aril. Shrubs or small trees. Leaves alternate, dotted, with convolute deciduous stipules. Flowers often brown.

Order 9.—*Anonaceæ.* Sepals 3-4. Petals 6, coriaceous, with a valvular æstivation. Stamens indefinite; filaments angular. Ovaries numerous. Fruit succulent or dry, with the carpels 1 or many-seeded, separate or consolidate. Albumen ruminate. Trees or shrubs. Leaves without stipules. Flowers axillary.

Sub-order—Schizandreæ. Trailing plants with unisexual flowers, monadelphous stamens, and solid albumen.

Order 10.—*Dilleniaceæ.* Sepals 5; 2 exterior, 3 interior. Petals 5. Stamens indefinite. Ovaries definite. Carpels baccate or 2-valved. Seeds surrounded by a pulpy aril. Embryo in solid fleshy albumen. Trees, shrubs or under-shrubs, rarely herbaceous, leaves without stipules. Flowers often yellow.

Alliance 3.—Umbellales. *Flowers usually disposed in umbels. Calyx superior. Disk epigynous, very thick, in two or more pieces. Carpels always* 1*-seeded. Stems usually hollow.*

Order 11.—*Apiaceæ* or *Umbelliferæ.* Calyx entire or 5-toothed. Petals 5, usually inflexed at the point. Stamens 5, alternate with the petals. Ovary 2-celled. Fruit consisting of 2 carpels, separable from a common axis. Seed pendulous. Herbaceous plants with fistular stems. Flowers in umbels.

Order 12.—*Araliaceæ.* Calyx entire or toothed. Petals 5-10. Stamens equal to the petals or twice as many, arising from without an epigynous disk. Ovary with more cells than two. Fruit succulent or dry, consisting of several 1-seeded cells. Seeds pendulous. Trees, shrubs, or herbaceous plants, with the habit of Apiaceæ.

Alliance 4.—Grossales. *Flowers never arranged in umbels. Calyx superior, epigynous. Disk, if present, not in several pieces. Carpels usually many-seeded, with the seeds distinct from the pericarp. Stem solid.*

Order 13.—*Grossulaceæ.* Calyx 4- or 5-parted, regular. Petals 5, minute. Stamens very short. Ovary 1-celled with 2 parietal placentæ. Berry 1-celled.

Order 14.—*Escalloniaceæ.* Calyx 5-toothed, petals forming a tube, but finally separating; æstivation imbricated. Stamens arising from the calyx. Disk conical, epigynous. Ovary 2-celled, with two large polyspermous placentæ in the axis; stigma 2-lobed. Fruit capsular, splitting by the separation of the cells at their base. Seeds minute; embryo in oily albumen. Shrubs with alternate, toothed, glandular, exstipulate leaves.

Order 15.—*Bruniaceæ.* Calyx 5-cleft, imbricated. Petals imbricated. Stamens alternate with the petals; anthers turned outward. Ovary half inferior

with from 1 to 3 cells. Ovules suspended, 1-2. Stigma simple. Fruit crowned by the permanent calyx. Seeds sometimes with a short aril. Branched heath-like shrubs. Flowers often capitate.

Alliance 5.—Berberales. *Anthers bursting by recurved valves.*

Order 16.—*Berberaceæ.* Sepals 3-4-6, in a double row. Petals sometimes with an appendage at the base. Stamens equal in number to the petals, and opposite to them; anthers opening elastically with a valve from the bottom to the top. Ovary solitary, 1-celled. Seeds attached to the bottom of the cell, 1, 2, or 3, albumen between fleshy and corneous. Shrubs or herbaceous perennial plants. Leaves alternate, compound, usually without stipules.

Alliance 6.—Pittosporales. *Carpels all combined into a solid ovary, with a single style. Placentæ central. Stamens never epigynous.*

Order 17.—*Vitaceæ.* Calyx small, nearly entire. Petals in æstivation valvate and often inflected at the point; stamens opposite them, inserted upon the disk. Ovary 2-celled; ovules erect, definite. Berry pulpy; albumen hard. Scrambling, climbing shrubs, with tumid separable joints. Leaves with stipules. Flowers small green.

Order 18.—*Pittosporaceæ.* Sepals deciduous, imbricated. Petals hypogynous, imbricated. Stamens 5, hypogynous. Ovary single, many-seeded. Fruit capsular or berried, with many-seeded cells which are sometimes incomplete. Albumen fleshy. Leaves simple, alternate, without stipules.

Order 19.—*Olacaceæ.* Calyx small, finally enlarged. Petals valvate, separate or cohering in pairs. Stamens definite, part fertile, part sterile, hypogynous. Ovary 1-celled, with 3 ovules pendulous from a central column. Fruit indehiscent, frequently surrounded by the enlarged calyx, 1-seeded. Seed pendulous. Trees or shrubs often spiny. Leaves alternate, entire, without stipules.

Order 20.—*Francoaceæ.* Calyx 4-cleft. Petals 4. Stamens sub-hypogynous, four times as numerous as the petals, alternately rudimentary. Ovary with 4 cells; ovules numerous. Capsule 4-valved. Seeds numerous, minute. Herbaceous plants, with lobed or pinnated leaves, without stipules. Petals persistent.

Order 21.—*Sarraceniaceæ.* Sepals 5, imbricate. Petals 5, unguiculate, concave. Stamens indefinite, hypogynous. Ovary 5-celled; stigma very large, peltate. Capsule crowned by the stigma. Seeds very numerous, minute. Herbaceous perennial plants, living in bogs. Leaves with a hollow urn-shaped petiole. Scapes bearing one large flower.

Group 2.—Epigynosæ.

Ovary inferior, usually having an epigynous disk. Seeds not having a disproportionate quantity of albumen.

Alliance 1.—Onagrales. *Æstivation not valvate. Placentæ central. Every part of the flower some regular multiple of two. In most cases herbaceous plants.*

Order 22.—*Onagraceæ.* Calyx tubular, 4-lobed, valvate. Petals regular, with a twisted æstivation. Stamens four or eight, inserted into the calyx. Stigma 4-lobed. Fruit many-seeded, with 4 cells. Seeds without albumen. Herbaceous plants or shrubs. Leaves alternate or opposite.

Sub-order—Circæeæ. Stamens 2. Disk large, cup-shaped. Ovary 2-celled. Ovules solitary, erect.

Sub-order—Halorageæ. Calyx minute. Petals minute or 0. Stamens often fewer than the lobes of calyx. Ovules solitary, pendulous.

Sub-order—Hydrocaryes. Calyx 4-parted. Petals 4. Stamens 4. Ovary 2-celled. Ovules solitary, pendulous. Fruit horned, 1-celled. Seed solitary with very unequal cotyledons. Floating plants.

Alliance 2.—Myrtales. *Æstivation not valvate. Placentæ occupying the centre of the fruit. Parts of the flower not a regular multiple of any number throughout. In most cases shrubby plants or trees.*

Order 23.—*Combretaceæ.* Calyx 4- or 5-lobed, deciduous. Stamens twice as many as the segments of the calyx, or three times as many. Ovary 1-celled, with

from 2 to 4 ovules, hanging from the apex of the cavity. Seed without albumen; cotyledons usually convolute. Trees or shrubs. Leaves without stipules.

Order 24.—*Alangiaceæ.* Calyx campanulate, 5-10-toothed. Petals 5-10, linear, reflexed. Stamens two or four times as numerous as the petals. Drupe 1-celled, bony. Seed inverted; albumen fleshy; cotyledons flat. Large trees. Branches often spiny. Leaves alternate, without stipules, entire, without dots.

Order 25.—*Rhizophoraceæ.* Calyx with the lobes varying from 4 to 13. Petals alternate with the lobes. Stamens twice or thrice their number. Ovary 2-celled, each cell containing two or more pendulous ovules. Fruit indehiscent, crowned by the calyx, 1-celled, 1-seeded. Seed without albumen. Coast trees or shrubs. Leaves opposite, with stipules between the petioles.

Order 26.—*Memecylaceæ.* Calyx 4- or 5-lobed or toothed. Stamens 8-10; anthers incurved. Ovary 2-4, rarely 8-celled; ovules solitary, pendulous. Fruit crowned by the calyx, indehiscent. Seeds without albumen; cotyledons foliaceous, convolute. Shrubs. Leaves opposite without stipules or dots.

Order 27.—*Melastomaceæ.* Calyx cohering with the angles of the ovary. Petals twisted in æstivation; filaments curved downwards in æstivation; anthers long, 2-celled, elongated beyond the insertion of the filament. Ovary with several cells, and indefinite ovules. Pericarp with placentæ attached to a central column. Seeds innumerable. Trees, shrubs, or herbaceous plants. Leaves opposite, with several ribs.

Order 28.—*Myrtaceæ.* Calyx 4- or 5-cleft, sometimes like a cap. Petals quincuncial. Stamens indefinite; anthers ovate, small. Ovary 1-2-4-5-6-celled. Fruit either dry or fleshy. Seeds indefinite; embryo without albumen. Trees or shrubs. Leaves opposite, with transparent dots, and a vein running parallel with their margin.

Sub-order ?—Barringtonieæ. Leaves alternate, stipulate, without dots.

Order 29.—*Lecythidaceæ.* Calyx 2- to 6-leaved, or urceolate. Petals with an imbricated æstivation. Stamens indefinite, epigynous, either cucullate or monadelphous. Ovary 2- to 6-celled; ovules attached to the axis. Fruit woody. Seeds several; embryo without albumen. Large trees, with alternate entire or toothed leaves, with minute stipules, without dots. Flowers large, showy, terminal.

Order 30.—*Philadelphaceæ.* Calyx persistent, having from 4 to 10 divisions. Petals convolute-imbricate. Stamens indefinite. Styles distinct, or consolidated; stigmas several. Capsule with 4 to 10 cells, many seeded. Seeds scobiform; aril loose, membranous. Albumen fleshy. Shrubs. Leaves deciduous, opposite, without dots or stipules. Flowers always white.

Alliance 3.—Cornales. *Æstivation of corolla valvate.*

Order 31.—*Hamamelaceæ.* Calyx in 4 pieces. Petals 4, linear. Stamens 8; 4 being sterile. Ovary 2-celled; ovules solitary, pendulous. Fruit capsular. Embryo in the middle of horny albumen. Shrubs. Leaves alternate with deciduous stipules. Flowers sometimes unisexual.

Order 32.—*Cornaceæ.* Sepals 4. Petals 4, oblong, broad. Stamens 4. Drupe crowned by the calyx, 2-celled. Seeds pendulous, solitary. Albumen fleshy. Trees or shrubs, seldom herbs. Leaves (except in one species) opposite, entire or toothed.

Order 33.—*Loranthaceæ.* Calyx with 2 bracts at the base. Corolla with 3, 4 or 8 petals, more or less united at the base, valvate; stamens opposite to them. Ovary 1-celled; ovule pendulous. Fruit succulent. Seed solitary; embryo cylindrical, longer than the fleshy albumen. Parasitical half shrubby plants. Leaves opposite, without stipules.

Alliance 4.—Cucurbitales. *Placentæ parietal. Flowers neither with a valvate corolla, nor with any other character appertaining to the preceding alliances.*

Order 34.—*Cucurbitaceæ.* Flowers unisexual. Calyx 5-toothed. Corolla 5-parted, scarcely distinguishable from the calyx, with strongly reticulated veins. Stamens 5, either distinct, or cohering in three parcels; anthers sinuous. Ovary with 3 placentæ; stigmas very thick, velvety or fringed. Fruit more or less succulent. Seeds flat, in an aril; embryo flat, with no albumen. Annual or perennial. Stem climbing by tendrils. Leaves palmated, or with palmate ribs, covered with asperities.

Order 35.—*Loasaceæ*. Calyx 5-parted. Petals 5 or 10, cucullate with an inflexed æstivation; the interior often much smaller. Stamens indefinite. Ovary with several placentæ or with 1 free central lobed one. Fruit capsular or succulent. Seeds numerous without aril; embryo in the axis of fleshy albumen. Herbaceous plants, hispid, with pungent hairs. Leaves without stipules.

Order 36.—*Cactaceæ*. Sepals indefinite, confounded with the petals. Stamens indefinite; filaments long, filiform. Ovary with numerous placentæ; stigmas numerous. Fruit succulent. Seeds without albumen. Succulent shrubs, usually destitute of leaves, and with spinous buds.

Order 37.—*Homaliaceæ*. Calyx funnel-shaped, with from 5 to 15 divisions. Petals equal to them in number. Glands in front of the segments of the calyx. Stamens from the base of the petals. Ovary half inferior, 1-celled with numerous ovules; styles from 3 to 5; as many placentæ as styles. Embryo in the middle of fleshy albumen. Trees or shrubs. Leaves alternate, with deciduous stipules.

Alliance 5.—Ficoidales. *Petals narrow and numerous. Placentation not parietal.*

Order 38.—*Mesembryaceæ* or *Ficoideæ*. Sepals definite, succulent. Petals indefinite, linear. Stamens indefinite. Ovary many-celled. Stigmas numerous. Capsule many-celled with a starry dehiscence. Embryo curved or spiral, on the outside of mealy albumen. Succulent shrubs or herbs. Flowers showy, opening only under bright sunshine.

Alliance 6.—Begoniales. *Flowers unisexual. Placentæ central.*

Order 39.—*Begoniaceæ*. Flowers unisexual. Sepals in the males 4; in the females 5. Stamens indefinite; anthers collected in a head, the connective very thick. Ovary winged, 3-celled, with 3 double polyspermous placentæ in the axis; stigmas 3, somewhat spiral. Fruit 3-celled, with an indefinite number of minute seeds; embryo without albumen. Herbaceous plants or under-shrubs. Leaves alternate, oblique. Stipules scarious.

Group 3.—Parietosæ.

Placentæ parietal, or arising from the base of carpels combined into a 1-celled ovary.

Alliance 1.—Cruciales. *Embryo curved. Albumen absent.*

Order 40.—*Brassicaceæ* or *Cruciferæ*. Petals 4, deciduous, cruciate. Petals 4, cruciate. Stamens 6, of which two are shorter. Ovary superior, with parietal placentæ, meeting in the middle, and forming a spurious dissepiment. Fruit a silique or silicule. Seeds attached by a funiculus, generally pendulous. Embryo with the radicle folded upon the cotyledons. Herbaceous plants. Leaves alternate. Flowers without bracts.

Order 41.—*Capparidaceæ*. Sepals 4. Petals 4, cruciate. Stamens definite or indefinite. Disk hemispherical, or elongated. Ovary stalked. Fruit 1-celled, most frequently with two polyspermous placentæ; embryo incurved. Herbaceous plants, shrubs, or trees, without true stipules. Leaves alternate.

Order 42.—*Resedaceæ*. Calyx many-parted. Petals lacerated, unequal. Disk 1-sided. Stamens perigynous, definite. Ovary sessile, 3-lobed, 1-celled, many seeded, with 3 parietal placentæ. Fruit opening at the apex. Embryo arcuate. Herbaceous plants with alternate leaves, and gland-like stipules.

Alliance 2.—Violales. *Stamens few, with no collection of abortive petals or stamens into an external ring. Embryo never curved.*

Order 43.—*Violaceæ*. Sepals 5, persistent, imbricate. Petals 5. Stamens hypogynous; filaments dilated, elongated beyond the anthers. Ovary 1-celled with 3 parietal placentæ; style with a hooded stigma. Capsule of 3 valves, bearing the placentæ in their axis. Herbaceous plants or shrubs. Leaves stipulate with an involute vernation.

Sub-order—Sauvagesiæ. Stamens opposite the petals. Five hypogynous scales. Seeds adhering to the edges of the valves.

Order 44.—*Samydaceæ*. Sepals 3, 5, or 7, usually coloured inside. Petals 0. Stamens from the tube of the calyx, 2, 3, or 4 times as many as the sepals;

filaments monadelphous. Ovary superior, 1-celled; stigma capitate, ovules indefinite, attached to parietal placentæ. Capsule coriaceous; with from 3 to 5 valves, many-seeded, often somewhat pulpy inside. Seeds fixed to the valves without order, with a fleshy aril; albumen fleshy. Trees or shrubs. Leaves alternate, with stipules, usually with pellucid markings, which are both round and linear.

Order 45.—*Moringaceæ.* Calyx of 5 nearly equal divisions, the tube lined with a fleshy disk. Corolla of 5 nearly equal petals. Stamens from the top of the tube of the calyx; filaments slightly petaloid. Ovary stipitate, with 3 placentæ. Fruit a long pod-like capsule with 3 valves. Seeds sometimes winged, embryo without albumen. Trees. Leaves pinnate, with an odd leaflet.

Order 46.—*Droseraceæ.* Sepals imbricate. Petals 5, hypogynous. Stamens distinct, either equal in number to the petals, or 2, 3, or 4 times as many. Styles 3-5. Capsule of 3 or 5 valves. Embryo in the axis of a fleshy or cartilaginous albumen. Herbaceous plants, often covered with glands. Leaves with stipulary fringes and a circinate vernation. Peduncles circinate.

Order 47.—*Frankeniaceæ.* Sepals 4-5, in a furrowed tube. Petals hypogynous, unguiculate, with appendages at the base of the limb. Stamens hypogynous; style 2- or 3-fid. Capsule 1-celled, enclosed in the calyx, 2-3- or 4-valved, many seeded. Seeds attached to the margins of the valves, very minute; embryo in the midst of albumen. Herbaceous plants or under-shrubs. Stems much branched. Leaves opposite, exstipulate, with a membranous sheathing base.

Alliance 3.—Passionales. *Flowers with a ring or crown of sterile stamens. Petioles generally glandular. Embryo never curved so that the radicle lies on the cotyledons.*

Order 48.—*Passifloraceæ.* Sepals 5, their tube lined with filamentous processes. Petals 5. Stamens monadelphous. Ovary stalked, 1-celled; styles 3; stigmas simple, clavate. Fruit with 3 polyspermous placentæ. Seeds with a brittle sculptured testa. Embryo in fleshy albumen. Usually climbers. Leaves alternate, with leafy stipules. Flowers often enclosed in an involucre.

Order 49.—*Papayaceæ.* Flowers unisexual. Calyx minute, toothed. Corolla gamopetalous; in the male with 5 lobes and 10 stamens; in the female divided nearly to the base. Ovary with 5 polyspermous placentæ; stigma sessile, 5-lobed, lacerated. Fruit succulent. Seeds enveloped in a loose mucous coat with pitted testa; embryo in the axis of fleshy albumen. Trees yielding an acrid milky juice. Leaves alternate.

Order 50.—*Flacourtiaceæ.* Sepals from 4-7. Petals equal to them in number. Stamens hypogynous, occasionally changed into nectariferous scales. Ovary roundish; stigmas several, more or less distinct. Fruit 1-celled, the centre filled with a thin pulp. Seeds few, attached to the surface of the valves in a branched manner. Embryo in the axis of albumen. Shrubs or trees. Leaves alternate without stipules.

Order 51.—*Malesherbiaceæ.* Calyx tubular, membranous, 5-lobed. Petals persistent, convolute, arising from without a rim or corona. Stamens 5 or 10, perigynous; filaments distinct. Ovary stipitate; styles 3, filiform. Fruit membranous more or less, many-seeded. Seeds arising either from the axis of the valves, or from their base; no aril; embryo in the midst of fleshy albumen. Herbaceous or half-shrubby plants. Leaves alternate, without stipules.

Order 52.—*Turneraceæ.* Calyx often coloured, with 5 lobes, imbricated. Petals 5, equal, twisted; stamens distinct. Ovary with 3 placentæ; ovules indefinite; styles 3 or 6, cohering more or less. Capsule 3-valved, the valves bearing the placentæ in the middle. Seeds with a thin aril on one side; embryo in the middle of fleshy albumen. Herbaceous plants. Leaves alternate, without stipules, with occasionally two glands at the apex of the petiole.

Alliance 4.—Bixales. *Polyandrous, without any crown of sterile stamens. Leaves usually dotted.*

Order 53.—*Bixaceæ.* Sepals 4-7, imbricated. Petals of a like number. Stamens indefinite, distinct. Ovary sessile; placentæ 4-7; style 1-2-4. Fruit many-seeded. Seeds enveloped in pulp. Albumen hardly present. Trees or shrubs. Leaves alternate with deciduous stipules and pellucid dots.

Group 4.—Calycosæ.

Calyx incompletely whorled, two of the sepals being exterior. Placentæ not parietal in the ovary. Fruit never inferior. Albumen, if present, of nearly the same volume as the embryo.

Alliance 1.—Guttales. *Stamens indefinite. Albumen absent. Petals and sepals equal in number.*

Order 54.—*Clusiaceæ* or *Guttiferæ*. Sepals 2 to 6 persistent. Petals hypogynous, 4 to 10. Stamens numerous, hypogynous. Disk fleshy, occasionally 5-lobed. Ovary 5- or many-celled; ovules solitary, erect, or ascending, or numerous and attached to central placentæ; style very short; stigma peltate or radiate. Seeds frequently nestling in pulp, frequently with an aril; albumen none. Trees or shrubs. Leaves without stipules, opposite, coriaceous.

Sub-order—Canelleæ. Seeds albuminous.

Order 55.—*Rhizobolaceæ*. Sepals 5, imbricated. Petals 5, thickish. Stamens extremely numerous, slightly monadelphous. Ovary 4-6-celled; stigma simple. Fruit of 4-6 combined nuts; each nut 1-seeded, 1-celled, with a thick double putamen. Seed uniform, without albumen; radicle very large, constituting nearly the whole of the almond-like nut. Trees. Leaves opposite, without stipules.

Order 56.—*Marcgraaviaceæ*. Sepals 2 to 7. Corolla hypogynous; sometimes gamopetalous. Stamens indefinite; anthers long. Ovary usually furrowed, many-celled, many-seeded; stigma simple or capitate; ovules numerous attached to a central placenta. Capsule coriaceous. Seeds very minute and numerous, nestling in pulp. Shrubs. Leaves alternate. Peduncles naked, or furnished with either simple or cucullate hollow bracts.

Order 57.—*Hypericaceæ*. Sepals 4-5, persistent, unequal, with glandular dots. Petals 4-5, hypogynous, twisted, oblique, often having black dots. Stamens indefinite, hypogynous. Styles several. Fruit a capsule or berry, of many valves and many cells. Seeds minute, indefinite; embryo straight, with no albumen.—Herbaceous plants, shrubs or trees. Leaves opposite, entire, sometimes dotted. Flowers generally yellow.

Sub-order—Ochrantheæ. Stamens definite. Stipules. Serrated leaves.

Alliance 2.—Theales. *Stamens indefinite in number. Albumen absent. The petals and sepals not equal to each other in number, gradually passing the one into the other.*

Order 58.—*Ternstromiaceæ*. Sepals 5 or 7, coriaceous, deciduous. Petals not equal in number to the sepals. Stamens numerous; monadelphous or polyadelphous. Ovary with several cells; styles filiform. Capsule 2-7-celled; usually with a central column. Seeds large, attached to the axis, very few; albumen none; cotyledons occasionally plaited lengthwise. Trees or shrubs. Leaves alternate, without stipules, now and then with pellucid dots.

Alliance 3.—Acerales. *Stamens definite in number. Flowers usually unsymmetrical in their parts, or more or less irregular; in the majority small and disposed in a compound inflorescence.*

Order 59.—*Aceraceæ*. Calyx imbricated. Petals inserted round an hypogynous disk. Stamens inserted upon an hypogynous disk, generally 8. Ovary 2-lobed; style 1; fruit of 2 parts, which are samaroid; each 1-celled; with one or two seeds; albumen none. Trees. Leaves opposite, wthiout stipules. Flowers often polygamous.

Order 60.—*Sapindaceæ*. Flowers polygamous. Calyx imbricated. Petals hypogynous, sometimes naked, sometimes with a doubled appendage in the inside, imbricated. Disk fleshy. Stamens 8-10, rarely 5-6-7. Ovary 3-celled, the cells containing 1, 2, 3, very seldom more, ovules. Fruit sometimes capsular, sometimes samaroid, sometimes fleshy and indehiscent. Seeds usually with an aril. Albumen 0. Trees, or shrubs which often climb and have tendrils.

Sub-order—Millingtonieæ. Flowers minute, very irregular. Stamens opposite the petals, 3 sterile, 2 fertile. Ovary 2-celled. Fruit a 1-celled drupe.

Order 61.—*Æsculaceæ*. Calyx campanulate, 5-lobed. Petals 4 or 5, unequal,

hypogynous. Stamens 7-8, unequal. Ovary 3-celled; ovules 2 in each cell. Fruit 1-2- or 3-valved. Seeds large, roundish, with a broad hilum; albumen none; embryo curved, germinating under ground. Trees or shrubs. Leaves opposite, without stipules, quinate or septenate. Racemes terminal.

Order 62.—*Polygalaceæ*. Sepals 5, very irregular, often glumaceous. Petals hypogynous, usually 3, of which 1 is anterior and larger than the rest. Stamens hypogynous, 8, usually in a tube; anthers innate, 1-celled and opening at their apex. Ovary with 2 or 3 cells; ovules solitary, pendulous. Seeds pendulous, with a caruncula next the hilum; albumen abundant. Shrubs or herbaceous plants. Leaves alternate, destitute of stipules. Pedicels with 3 bracts.

Order 63.—*Vochyaceæ*. Sepals 4-5, the upper one calcarate. Petals 1, 2, 3, or 5. Stamens 1-5, from the bottom of the calyx. Ovary superior, 3-celled; ovules solitary or twin, attached to the base of the axis. Capsule 3-cornered, 3-celled, 3-valved. Seed without albumen, erect. Trees. Branches opposite, when young 4-cornered. Leaves opposite, with 2 stipules.

Alliance 4.—Cistales. *Flowers regular. Albumen present in the seeds.*

Order 64.—*Elatinaceæ*. Sepals 3-5. Petals hypogynous. Stamens hypogynous. Ovary 3-5-celled; styles 3-5; stigmas capitate. Fruit capsular. Seeds numerous, embryo straight, with but little albumen. Annuals. Leaves opposite with stipules. Flowers minute.

Order 65.—*Linaceæ*. Sepals 3-4-5, imbricated, persistent. Petals hypogynous, unguiculate, twisted. Stamens united in an hypogynous ring. Ovary with about as many cells as sepals. Styles equal in number to the cells; stigmas capitate. Capsule many-celled. Seeds in each cell single, inverted; albumen present. Herbaceous plants or small shrubs. Leaves without stipules, usually alternate. Petals fugitive.

Order 66.—*Hugoniaceæ*. Calyx without an involucre, permanent, the sepals very unequal. Petals 5, shortly unguiculate, twisted. Stamens 10, hypogynous, slightly monadelphous. Ovary stalked, 5-celled; ovules 2, pendulous. Styles 5, distinct. Fruit containing 5 bony nuts. Embryo in the axis of fleshy albumen. Shrubs. Leaves alternate, with subulate stipules. Peduncles often transformed into circinate spines.

Order 67.—*Chlenaceæ*. Involucre 1-2-flowered. Sepals 3, small. Petals 5 or 6, hypogynous. Stamens either very numerous or 10. Ovary 3-celled; style 1. Capsule 3-celled. Seeds solitary or numerous, suspended; albumen firm. Trees or shrubs. Leaves alternate, with stipules.

Order 68.—*Cistaceæ*. Sepals 5, persistent, unequal, the three inner twisted. Petals 5, crumpled, twisted in a direction contrary to that of the sepals. Stamens indefinite, hypogynous. Ovary 1- or many-celled; ovules with their foramen at their apex; style single; stigma simple. Fruit either 1-celled with parietal placentæ, or imperfectly 5- or 10-celled. Seeds indefinite. Embryo inverted, either spiral or curved in the midst of mealy albumen. Radicle remote from the hilum. Shrubs or herbaceous plants. Leaves usually entire, stipulate or exstipulate.

Order 69.—*Reaumuriaceæ*. Calyx 5-parted, surrounded externally by imbricated bracts. Petals 5, hypogynous. Stamens hypogynous. Ovary superior; styles several, filiform. Fruit with 2 to 5 valves. Seeds definite, villous, erect; embryo surrounded by a mealy albumen; radicle next the hilum. Shrubs. Leaves fleshy, scale-like, without stipules. Flowers solitary.

Group 5.—Syncarposæ.

The carpels united into a solid pistil. Calyx not having the sepals in a broken whorl. Placentæ not parietal. Ovary not inferior. Carpels not placed obliquely upon a central gynobase; or if they are, then either in more rows than one or of a larger number than 5.

Alliance 1.—Malvales. *Æstivation of calyx valvate. Carpels 4 or more. Stamens generally monadelphous; the calyx long and tubular when that is not the case. Hairs mostly starry.*

Order 70.—*Sterculiaceæ*. Petals hypogynous, convolute, often saccate at the base. Stamens definite or indefinite, some among them often sterile; anthers

2-celled, sometimes anfractuose. Pistil often seated upon a gynophore. Styles equal in number to the carpels; ovules erect. Seeds often winged, sometimes woolly; albumen oily or fleshy, rarely wanting; cotyledons foliaceous, flat, and plaited. Trees or shrubs. Leaves alternate, with stipules.

Order 71.—*Malvaceæ*. Sepals 3 or 4, hypogynous, twisted. Stamens indefinite, monadelphous; anthers 1-celled, reniform. Ovary formed by the union of several carpels; styles the same number as the carpels. Fruit either capsular or baccate; albumen none; embryo curved, with twisted and doubled cotyledons. Herbaceous plants, trees, or shrubs. Leaves alternate, stipulate.

Order 72.—*Elæocarpaceæ*. Sepals 4 or 5. Petals 4 or 5, hypogynous, lobed or fringed at the point. Disk glandular. Stamens hypogynous or perigynous, some multiple of the sepals; filaments short, distinct; anthers long, filiform, 4-cornered, opening by an oblong pore at the apex. Ovary two or many-celled. Fruit variable. Seeds 1, 2, or more in each cell; albumen fleshy. Trees or shrubs. Leaves alternate, simple, with deciduous stipules.

Order 73.—*Dipteraceæ*. Calyx tubular, 5-lobed, unequal, afterwards enlarged, imbricated. Petals contorted. Stamens indefinite, hypogynous, distinct; anthers subulate, opening longitudinally towards the apex. Ovary without a disk, few-celled; ovules in pairs, pendulous; style single. Fruit surrounded by the calyx, having tough, leafy, enlarged, permanent divisions. Seed single, without albumen. Cotyledons crumpled. Trees. Leaves alternate, involute invernation; stipules deciduous.

Order 74.—*Tiliaceæ*. Sepals 4 or 5. Petals 4 or 5, usually with a little pit at their base. Stamens hypogynous, distinct; anthers 2-celled. Ovary single, composed of from 4 to 10 carpels; style one; stigmas as many as the carpels. Fruit dry. Seeds numerous; embryo erect in the axis of fleshy albumen, with flat foliaceous cotyledons. Trees or shrubs, very seldom herbaceous plants. Leaves stipulate, alternate.

Order 75.—*Lythraceæ*. Calyx monosepalous. Petals inserted between the lobes of the calyx, very deciduous. Stamens inserted into the tube of the calyx below the petals. Ovary 2- or 4-celled; style filiform; capsule membranous, covered by the calyx, usually 1-celled. Seeds numerous, without albumen. Herbs, rarely shrubs. Branches frequently 4-cornered. Leaves without stipules.

Alliance 2.—Meliales. *Æstivation of calyx imbricated. Carpels 4 or a larger number. Stamens very generally monadelphous in a kind of cup. Seldom or never hairy.*

Order 76.—*Meliaceæ*. Sepals 3, 4, or 5. Petals hypogynous, usually valvate. Stamens twice as many as the petals; filaments cohering in a long tube; anthers sessile within the orifice of the tube. Ovary with 3, 10, 12 cells; ovules 1-2 in each cell. Fruit often 1-celled. Seeds without albumen, not winged. Trees or shrubs. Leaves alternate, without stipules.

Order 77.—*Cedrelaceæ*. Calyx 4-5-cleft. Petals 4-5. Stamens 8-10, either united or distinct. Style and stigma simple. Seeds flat-winged. Trees with timber which is usually compact, scented and beautifully veined. Leaves alternate, without stipules.

Order 78.—*Humiriaceæ*. Calyx 5-parted. Stamens hypogynous, numerous, monadelphous; anthers with a fleshy connective extended beyond the lobes. Ovary 5-celled; ovules 1-2 suspended; style simple. Fruit drupaceous. Embryo in fleshy albumen. Trees or shrubs. Leaves alternate, without stipules.

Order 79.—*Aurantiaceæ*. Calyx urceolate or campanulate, short. Petals 3-5, inserted upon the outside of an hypogynous disk. Stamens inserted upon an hypogynous disk; filaments sometimes combined in one or several parcels. Ovary many-celled, style 1; stigma thickish. Fruit many-celled, filled with pulp. Seeds usually pendulous; raphe and chalaza distinctly marked. Trees or shrubs, almost always smooth and filled with transparent receptacles of oil. Leaves alternate, often compound, always articulated with the petiole.

Order 80.—*Spondiaceæ*. Calyx 5-cleft. Petals 5, inserted below a disk surrounding the ovary. Stamens 10, perigynous. Disk annular. Ovary 2-5-celled, styles 5; stigmas obtuse; ovule 1 in each cell, pendulous. Fruit drupaceous, 2-5-celled. Seeds without albumen. Trees without spines. Leaves alternate, without pellucid dots.

Alliance 3.—Rhamnales. *Æstivation of the calyx valvate. Carpels fewer than 4, sometimes slightly adhering to the calyx. Hairs if present never starry. All shrubs.*

Order 81.—*Rhamnaceæ.* Calyx 4-5-cleft, valvate. Petals distinct, inserted into the orifice of the calyx. Stamens definite, opposite the petals. Ovary superior, or half-superior, 2- 3- or 4-celled; ovules solitary, erect. Albumen fleshy; embryo with large flat cotyledons, and a short inferior radicle. Trees or shrubs. Leaves alternate with minute stipules. Flowers axillary or terminal, minute.

Order 82.—*Chailletiaceæ.* Sepals with an incurved valvate æstivation. Petals alternate with the sepals, and arising from the base of the calyx. Stamens 5; glands 5, hypogynous, opposite the petals. Ovary 2- 3-celled. Ovules twin, pendulous; style simple. Fruit drupaceous, 1- 2- or 3-celled. Seeds without albumen. Trees or shrubs. Leaves alternate, with two stipules. Flowers small, axillary.

Order 83.—*Tremandraceæ.* Sepals 4 or 5, equal, valvular, deciduous. Petals involute, much larger than the calyx. Stamens hypogynous, 2 before each petal; anthers 2- or 4-celled, opening by a pore at the apex. Ovary 2-celled; ovules from 1 to 3, pendulous. Fruit capsular. Seeds with a thickened appendage at the apex; embryo in the axis of a fleshy albumen. Slender heath-like shrubs. Leaves without stipules. Flowers often large and showy.

Order 84.—*Nitrariaceæ.* Calyx 5-toothed. Corolla of 5 petals which arise from the calyx, with an inflexed valvular æstivation. Stamens 3 times the number of the petals, perigynous. Ovary 3- or more-celled, with a fleshy style; ovules pendulous, by means of a long funiculus. Fruit drupaceous. Seeds with no albumen. Shrubs, with succulent alternate leaves, which are sometimes fascicled.

Order 85.—*Burseraceæ.* Calyx persistent, with from 2 to 5 divisions. Petals 3-5, inserted below a disk; æstivation valvate. Stamens 2 or 4-times as many as the petals, perigynous. Ovary 2-5-celled; style 1; ovules in pairs, attached to the axis. Fruit drupaceous. Seeds without albumen. Trees or shrubs. Leaves alternate, equally pinnate, occasionally with stipules, usually without pellucid dots.

Alliance 4.—Euphorbiales. *Æstivation of calyx imbricated. Carpels fewer than four; very often three. Hairs frequently starry if present.*

Order 86.—*Euphorbiaceæ.* Flowers monœcious or diœcious. Calyx lobed, sometimes wanting. Corolla consisting of petals or scales, or absent. Stamens definite or indefinite. Ovary superior, 2- or 3-celled; ovules solitary or twin, suspended; styles equal in number to the cells; stigma compound or single. Fruit generally consisting of 3 dehiscent cells, separating with elasticity from their common axis; embryo in fleshy albumen. Trees, shrubs, or herbaceous plants, often abounding in acrid milk. Leaves opposite or alternate, usually with stipules. Flowers sometimes enclosed within an involucre.

Order 87.—*Empetraceæ.* Flowers unisexual. Sepals hypogynous, imbricated scales. Stamens equal in number to the inner sepals, and alternate with them. Ovary 3- 6- or 9-celled; ovules solitary, ascending; stigma radiating. Fruit fleshy, 3- 6- or 9-celled; the coating of the cells bony; embryo in the axis of fleshy watery albumen. Small acrid shrubs with heath-like evergreen leaves and minute flowers.

Order 88.—*Stackhousiaceæ.* Calyx 1-leaved, 5-cleft, with an inflated tube. Petals 5, arising from the top of the tube of the calyx; their claws combined in a tube longer than the calyx. Stamens 5, unequal, arising from the throat of the calyx. Ovary 3- or 5-lobed, the lobes with a single erect ovule; styles from 3 to 5, sometimes combined. Fruit of from 3 to 5 indehiscent pieces. Embryo in the axis of fleshy albumen. Herbaceous plants. Leaves simple, alternate. Stipules very minute.

Order 89.—*Fouquieraceæ.* Sepals 5, imbricated. Petals in a long tube, regular. Stamens 10-12, inserted on the calyx. Style filiform; ovules numerous. Capsule 3-celled, 3-valved; seeds winged. Embryo in the centre of thin fleshy albumen. Trees or shrubs. Leaves fleshy, clustered in the axil of a spine.

Order 90.—*Celastraceæ.* Sepals 4 or 5, imbricated, inserted into the margin

of an expanded torus. Petals imbricate. Stamens alternate with the petals, inserted into the disk. Disk large, expanded, flat, closely surrounding the ovary. Ovary with 3 or 4 cells; ovules ascending; albumen fleshy. Shrubs. Leaves simple. Flowers in axillary cymes, minute.

Sub-order—Hippocrateæ. Sepals and petals 5. Stamens 3.

Sub order—Trigonieæ. Sepals and petals unequal, the latter papilionaceous. Stamens 10-12, monadelphous, out of the centre.

Order 91.—*Staphyleaceæ.* Sepals 5, coloured, imbricated. Petals 5, imbricated. Stamens alternate with the petals, perigynous. Disk large, urceolate. Ovary 2- or 3-celled, superior; ovules erect; styles 2 or 3, cohering. Fruit membranous or fleshy. Seeds with a bony testa; hilum large; albumen none. Shrubs. Leaves opposite, pinnate, with both common and partial stipules.

Order 92.—*Malpighiaceæ.* Sepals generally with a definite number of conspicuous glands. Petals 5, unguiculate; stamens seldom fewer. Ovary 1, of 3 carpels, more or less combined; ovules suspended. Fruit dry or berried. Seeds without albumen. Small trees or shrubs, sometimes climbing. Leaves opposite, with stipules.

Sub-order—Erythroxyleæ. Petals sessile, with a plaited scale at the base. Albumen horny. Shrubs or trees. Young shoots covered with imbricated scales. Leaves alternate with axillary stipules.

Alliance 5.—Silenales. *Embryo rolled round mealy albumen; or if this is not the case, herbaceous plants with the joints of the stem tumid; or with scales replacing leaves upon rod-like branches. Almost all herbs or small shrubs.*

Order 93.—*Portulacaceæ.* Sepals 2. Petals generally 5. Stamens inserted irregularly into the calyx, or hypogynous, variable in number. Ovary 1-celled; style single, stigmas several. Capsule 1-celled. Seeds attached to a central placenta. Embryo curved round the albumen. Succulent shrubs or herbs. Leaves without stipules, sometimes with membranous ones. Flowers usually ephemeral.

Order 94.—*Silenaceæ.* Sepals 4-5, united into a permanent tube. Petals stalked. Stamens hypogynous, definite. Ovary stalked, usually many-seeded with a free central placenta. Stigmas sessile, 2-5. Capsule 2-5 valved. Seeds usually with the embryo curved round mealy albumen. Herbaceous plants with opposite undivided exstipulate leaves, and tumid nodes.

Order 95.—*Alsinaceæ.* Sepals 4-5. Petals often 2-lobed, deciduous, on the outside of a ring, which is more or less perigynous. Stamens inserted into the ring. Ovary 1-celled, many-seeded. Stigmas 2-5, linear, sessile. Capsule 1-celled. Seeds attached to a free central placenta. Embryo curved round mealy albumen. Herbaceous plants with tumid joints. Leaves opposite, undivided, often connate. Stipules none.

Order 96.—*Tamaricaceæ.* Calyx 4-or 5-parted, persistent. Petals withering. Stamens hypogynous, distinct or monadelphous. Stigmas 3. Capsule 3-valved, 1-celled, many-seeded. Seeds ascending, comose; embryo straight. Shrubs or herbs, with rod-like branches. Leaves alternate, resembling scales.

Order 97.—*Illecebraceæ.* Sepals 3, 4, or 5. Petals minute. Stamens perigynous. Ovary superior; styles 2-5. Fruit small, dry, 1-celled, rarely 3-celled. Seeds upon a central placenta, embryo lying on one side of the albumen. Herbaceous or half-shrubby plants, with entire leaves and scarious stipules. Flowers minute, with scarious bracts.

Group 6.—Gynobaseosæ.

Carpels about 5 in a single whorl, diverging at the base in consequence of the interposition of a conical gynobase. Stamens usually hypogynous.

Alliance 1.—Rutales. *Style single, or leaves marked with pellucid dots.*

Order 98.—*Ochnaceæ.* Sepals persistent, imbricated. Petals hypogynous, sometimes twice as many as the sepals. Stamens 5, 10, or indefinite, hypogynous; anthers opening by pores. Carpels upon an enlarged fleshy disk, style one; ovule erect. Fruit of many pieces, somewhat drupaceous, 1-seeded. Seeds without albumen. Very smooth trees or shrubs. Leaves alternate, with stipules.

Order 99.—*Simarubaceæ.* Flowers hermaphrodite, or unisexual. Calyx in 4 or 5 divisions. Petals longer; æstivation twisted. Stamens arising from the back of an hypogynous scale. Ovary 4- or 5-lobed upon a stalk, each cell with 1 suspended ovule; style simple. Fruit indehiscent; embryo without albumen. Trees or shrubs. Leaves without stipules, alternate, without dots.

Order 100.—*Rutaceæ.* Flowers hermaphrodite, sometimes irregular. Sepals 4-5. Petals sometimes combined. Stamens definite, hypogynous, on the outside of a cup-like disk. Ovary few-celled; ovules 2-4; style single, occasionally divided near the base. Fruit capsular. Embryo with or without albumen; radicle superior. Trees or shrubs (or herbs). Leaves exstipulate, dotted.

Order 101.— *Zygophyllaceæ.* Flowers hermaphrodite. Calyx convolute. Petals unguiculate. Stamens dilated at the base, sometimes placed on the back of a small scale, hypogynous. Ovary with a disk with 4 or 5 cells; ovules pendulous or erect; style simple. Fruit capsular, rarely fleshy, with angles or wings. Seeds fewer than the ovules; radicle superior; albumen whitish. Herbaceous plants, shrubs or trees; branches often articulated at the joints. Leaves opposite, with stipules, not dotted.

Order 102.—*Xanthoxylaceæ.* Flowers unisexual. Calyx in 3, 4, or 5 divisions. Petals usually longer than the calyx, convolute. Stamens equal to the petals in number, or twice as many. Ovary of the same number of carpels as there are petals, or of a smaller number; ovules 2; styles more or less combined. Fruit berried or membranous, sometimes consisting of several drupes or 2-valved capsules. Seeds solitary or twin, pendulous, usually smooth and shining; embryo lying within fleshy albumen; radicle superior. Trees or shrubs. Leaves without stipules, with pellucid dots.

Alliance 2.—Geraniales. *Styles distinct, at least near the point. Carpels combined in the ovary. Leaves never dotted. Stamens very often monadelphous.*

Order 103.—*Geraniaceæ.* Sepals 5, ribbed. Petals 5, unguiculate. Stamens definite, hypogynous, often monadelphous. Fruit of 5 elastic cocci rolling back from a long-beaked gynobase to which the hardened styles adhere. Seeds solitary, pendulous, without albumen. Cotyledons convolute and plaited. Herbs or shrubs with stipulate leaves. Stems tumid, and separable at the joints.

Order 104.—*Balsaminaceæ.* Sepals irregular; the odd sepal spurred. Petals irregular. Stamens 5, symmetrical. Carpels consolidated into a 5-celled ovary. Fruit capsular, with 5 elastic valves. Seeds solitary, or numerous, suspended; albumen none. Succulent herbaceous plants. Leaves without stipules.

Sub-order.—Tropæoleæ. Fruit indehiscent; the lobes fleshy and 1-seeded.

Order 105.—*Oxalidaceæ.* Sepals 5, equal. Petals equal, unguiculate. Stamens 10, more or less monadelphous. Styles 5; stigmas capitate. Fruit capsular, membranous, with 5 cells. Seeds few, within a fleshy integument, which expels the seeds with elasticity. Albumen between cartilaginous and fleshy. Herbaceous plants, undershrubs, or trees. Leaves alternate, compound.

Alliance 3.—Coriales. *Styles and carpels perfectly distinct.*

Order 106.—*Coriariaceæ.* Flowers hermaphrodite, monœcious or dicœcious. Calyx 5-parted. Petals 5, fleshy, with an elevated keel. Stamens 10. Ovary 5-celled, 5-angled; stigmas 5, subulate. Ovules solitary. Carpels 5, indehiscent, 1-seeded, sometimes surrounded with glandular lobes. Albumen none. Shrubs with opposite branches. Leaves simple, entire.

Order 107.—*Surianaceæ.* Calyx 5-parted. Petals equal, shortly clawed. Stamens indefinite, hypogynous. Carpels 5, 1-celled with 2 ascending ovules, stigmas simple. Pericarp woody. Seed solitary, erect. Embryo annular, without albumen. Woody plants. Leaves alternate, without stipules.

Alliance 4.—Flörkeales. *Herbs. A simple style. Fruit divided into deep lobes. Gynobase never fleshy. Stamens perigynous.*

Order 108.—*Limnanthaceæ.* Calyx 3- 5-parted, valvate. Petals convolute. Stamens perigynous; the filaments opposite the sepals having a projection on the outside. A thin perigynous disk. Carpels combined by a single style. Nuts 3-5, berried, 1-seeded. Seed erect; embryo large, amygdaloid, without albumen. Soft herbaceous plants. Leaves divided, without stipules. Flowers axillary.

Group 7.—Apocarposæ.

Carpels distinct, either wholly or in part. Ovary with neither a gynobase nor parietal placentæ. Calyx not in a broken whorl. No epigynous disk.

Alliance 1.—Rosales. *Albumen wholly absent.*

Order 109.—*Rosaceæ.* Calyx with a disk lining the tube. Petals perigynous, equal. Stamens indefinite, arising from the calyx. Ovaries superior, solitary or several, 1-celled; sometimes cohering into a plurilocular pistil; styles lateral. Fruit 1-seeded nuts, or acini, or follicles, containing several seeds. Embryo straight. Herbaceous plants or shrubs. Leaves simple or compound, alternate, usually with stipules.

Sub-order.—Pomeæ. Calyx superior. Ovary adhering more or less to the sides of the calyx and each other; ovules ascending. Fruit a pome. Albumen none. Trees or shrubs.

Sub-order.—Amygdaleæ. Calyx inferior. Carpel solitary. Fruit a drupe. Trees or shrubs.

Sub-order.—Sanguisorbeæ. Flowers often unisexual. Calyx with a thickened tube. Petals none. Stamens definite. Ovary solitary, simple. Ovule solitary. Nut solitary, enclosed in the tube of the calyx. Embryo without albumen. Herbaceous plants or undershrubs, occasionally spiny.

Order 110.—*Fabaceæ* (or *Leguminosæ*). Calyx inferior, the segments often unequal, and variously combined. Petals either papilionaceous or regularly spreading. Stamens definite or indefinite, perigynous, or hypogynous. Ovary simple, superior. Fruit a legume. Seeds destitute of albumen. Herbaceous plants, shrubs, or trees. Leaves alternate; petiole tumid at the base. Stipules 2.

Sub-order.—Cæsalpinieæ. Petals regularly spreading, imbricated. Stamens perigynous.

Sub-order.—Mimoseæ. Sepals and petals valvate. Stamens hypogynous.

Order 111.—*Connaraceæ.* Calyx 5-parted, persistent. Petals inserted on the calyx, imbricated. Stamens hypogynous, filaments usually monadelphous. Ovary solitary and simple, or several; ovules 2, ascending; stigmas usually dilated. Fruit dehiscent. Seeds often with an aril. Trees or shrubs. Leaves compound, not dotted, alternate, without stipules.

Order 112.—*Chrysobalanaceæ.* Calyx 5-lobed. Petals more or less irregular, either 5 or none. Stamens definite or indefinite, usually irregular. Ovary superior, solitary, cohering more or less on one side with the calyx; ovules erect. Fruit, a drupe with 1 or 2 cells. Seed solitary, erect. Embryo with no albumen. Trees or shrubs. Leaves simple, alternate, stipulate, with veins that run parallel with each other from the midrib to the margin.

Order 113.—*Calycanthaceæ.* Sepals and petals confounded, indefinite, combined in a fleshy tube. Stamens inserted in a fleshy rim. Anthers adnate, turned outwards. Ovaries several, simple; ovules solitary. Nuts enclosed in the fleshy tube of the calyx, 1-seeded. Albumen none; cotyledons convolute. Shrubs with square stems. Leaves opposite, simple, without stipules.

Alliance 2.—Saxales. *Carpels two, diverging at the end, many-seeded. Embryo in the axis of albumen.*

Order 114.—*Baueraceæ.* Sepals inferior. Petals the same number. Stamens indefinite; anthers bursting by pores. Carpels little inferior. Fruit capsular. Shrubs. Leaves toothed, ternate, opposite, without stipules.

Order 115.—*Cunoniaceæ.* Calyx 4- or 5-cleft, half superior. Petals 4 or 5. Stamens perigynous, definite. Styles sometimes combined. Fruit capsular or indehiscent. Embryo in the axis of fleshy albumen. Trees or shrubs. Leaves opposite, compound, or simple, with interpetiolar stipules.

Order 116.—*Saxifragaceæ.* Calyx superior or inferior. Petals 5, or none. Stamens 5-10, perigynous or hypogynous; anthers bursting longitudinally. Disk hypogynous or perigynous, rarely consisting of 5 scales. Styles none. Stigmas sessile on the tips of the lobes of the ovary. Fruit membranous. Seeds numerous, very minute. Embryo taper, in the axis of fleshy albumen. Herbaceous plants. Leaves simple.

Alliance 3.—Crassales. *Carpels several, quite distinct, continuous with the styles. Seeds very numerous with albumen.*

Order 117.—*Crassulaceæ*. Sepals from 3 to 20. Petals either distinct or cohering. Stamens inserted with the petals. Hypogynous scales several, 1 at the base of each carpel. Ovaries of the same number as the petals, opposite to which they are placed. Fruit of several follicles, opening in their face. Seeds variable in number. Succulent herbs or shrubs. Stipules none. Flowers usually in cymes.

Alliance 4.—Balsamales. *Carpels neither two and diverging at the apex; nor numerous with an hypogynous scale. Leaves and bark abounding in balsamic juice.*

Order 118.—*Amyridaceæ*. Calyx minute. Petals 4-5, imbricated. Stamens definite, hypogynous. Ovary superior, 1-celled; stigma capitate; ovules pendulous. Fruit indehiscent, glandular. Seed without albumen; radicle superior. Resinous trees or shrubs. Leaves compound, with pellucid dots.

Order 119.—*Anacardiaceæ*. Flowers unisexual. Calyx small. Petals perigynous, imbricated. Stamens usually definite. Disk fleshy, hypogynous. Ovary single, very rarely 5 or 6; styles 1 or 3, occasionally 4; ovule solitary, attached by a cord to the bottom of the cell. Fruit indehiscent. Seed without albumen. Trees or shrubs, with a resinous caustic juice. Leaves alternate, without pellucid dots.

Sub-Class II.—INCOMPLETÆ.

Corolla absent. Calyx consisting of distinct sepals, or of several combined into a tube; very often incomplete; often absent.

Group 1.—Rectembryosæ.

Calyx exceedingly imperfect, often rudimentary. Embryo straight, with or without albumen.

Alliance 1.—Amentales. *Flowers in catkins. Carpels two or more, combined. Trees or arborescent shrubs.*

Order 120.—*Corylaceæ* or *Cupuliferæ*. Flowers unisexual. Stamens 5 to 20. Ovaries crowned by the rudiments of a calyx, within a coriaceous involucre, with several cells and several ovules; ovules pendulous. Fruit a 1-celled nut, enclosed in the involucre. Seeds solitary. Trees or shrubs. Leaves with stipules, alternate.

Order 121.—*Betulaceæ*. Flowers unisexual, monœcious, males sometimes having a calyx. Stamens definite, usually distinct. Ovary superior, 2-celled; ovules pendulous. Fruit membranous, indehiscent, 1-celled. Seeds pendulous; albumen none. Trees or shrubs. Leaves alternate, with stipules.

Order 122.—*Scepaceæ*. Flowers dicœcious. Males in catkins. Calyx minute and membranous. Stamens 2-5. Females in axillary racemes. Calyx of six sepals, inferior. Ovary with two cells; style 0; stigma with short lobes; ovules pendulous, with a broad scale projecting from the placenta and covering over the foramen. Capsule 2-celled. Seeds enveloped in a succulent aril; embryo in the axis of albumen. Trees. Leaves coriaceous, alternate, with membranous stipules.

Alliance 2.—Urticales. *Carpels solitary, or more than one combined in a syncarpous pistil. Stamens continuous, without sheaths. Flowers never producing fruit with a cupule.*

Order 123.—*Garryaceæ*. Flowers dicœcious. Males: calyx 4-leaved. Stamens 4. Females: calyx superior, 2-toothed. Ovary 1-celled; ovules 2, pendulous. Pericarp berried, indehiscent, 2-seeded. Embryo very minute, in the base of fleshy albumen. A shrub. Leaves opposite, without stipules. Flowers in pendulous amentaceous racemes.

Order 124.—*Hensloviaceæ*. Flowers dicœcious. Calyx with a woolly disk, valvate. Males: stamens 5, perigynous; anthers 2-celled, with a broad connective and oblique lobes, bursting longitudinally. Females: ovary superior, 2-celled; ovules indefinite. Trees with opposite entire exstipulate leaves.

Order 125. — *Trewiaceæ*. Flowers diœcious. Males: sepals 3-4, valvate. Stamens numerous. Females: calyx inferior. Style 4-cleft. Drupe 4-celled, with a single seed in each. Embryo inverted and furnished with albumen. A tree. Leaves opposite, exstipulate, entire.

Order 126.— *Urticaceæ*. Flowers monœcious or diœcious. Calyx membranous. Stamens definite, turned backwards with elasticity. Ovary superior, simple; ovule solitary; stigma simple. Fruit, a nut. Embryo with or without albumen; radicle always superior. Trees, shrubs or herbs, sometimes lactescent. Leaves alternate, usually covered with asperities or stinging hairs; with stipules.

Sub-order.—*Ceratophylleæ*. Calyx many-parted. Stamens 12-20. Nut 1-seeded, terminated by the hardened stigma. Seed pendulous; embryo with 4 cotyledons, and a many-leaved placenta.

Order 127. *Ulmaceæ*. Flowers hermaphrodite. Calyx campanulate, inferior, irregular. Stamens definite. Ovary 2-celled; ovules solitary, pendulous. Fruit 1- or 2-celled, indehiscent, membranous or drupaceous. Seed pendulous; albumen none; radicle superior. Trees or shrubs, with scabrous alternate leaves and stipules.

Order 128.—*Stilaginaceæ*. Flowers unisexual. Calyx 3-5-parted. Stamens 2 or more, from a tumid receptacle. Anthers 2-lobed, with vertical lobes opening transversely. Ovary superior; stigma 3- 4-toothed. Fruit drupaceous. Seed solitary, suspended, albuminous. Trees or shrubs. Leaves alternate, stipulate.

Order 129. — *Myricaceæ*. Flowers unisexual, amentaceous, achlamydeous. Stamens 6 or 8. Ovary 1-celled, surrounded by several hypogynous scales; ovule solitary, erect; stigmas 2. Fruit drupaceous, or dry and dehiscent. Seed solitary, erect; radicle superior. Leafy shrubs, with resinous glands and dots, leaves alternate.

Order 130.—*Juglandaceæ*. Flowers unisexual. Calyx in the males membranous; in the females superior. Petals in the males 0; in the females occasionally present. Stamens indefinite, hypogynous. Ovary inferior, incompletely 2- 4-celled; ovule solitary, erect. Fruit drupaceous, 1-celled, with 4 imperfect partitions. Seed 4-lobed; radicle superior. Trees. Leaves alternate, pinnated, without pellucid dots or stipules.

Alliance 3.—Casuarales. *Carpels solitary. Stems jointed and furnished with sheaths.*

Order 131. — *Casuaraceæ*. Flowers unisexual. Males. Flowers whorled about the articulations of the jointed rachis. Bracts membranous. Stamen 1. Females in dense spikes. Rachis not jointed. Calyx 0. Ovary lenticular. Styles 2. Caryopsides winged. Seed erect without albumen. Branching weeping trees, with jointed shoots. Leaves 0.

Alliance 4.—Datiscales. *Carpels several. Seeds numerous. Leaves alternate.*

Order 132.—*Datiscaceæ*. Flowers unisexual. Calyx of the males in several pieces; of the females superior, toothed. Stamens several. Ovary 1-celled, with polyspermous parietal placentæ. Fruit capsular, 1-celled. Seeds with a cupulate strophiole; embryo without albumen. Herbaceous branched plants. Leaves alternate without stipules.

Order 133.—*Lacistemaceæ*. Calyx in several narrow divisions, inferior. Stamens hypogynous, on one side of the ovary, with a thick 2-lobed connective. Ovary superior, 1-celled, with several ovules attached to parietal placentæ. Fruit capsular, 1-celled. Seed suspended, with a fleshy aril; albumen fleshy; embryo inverted. Small trees or shrubs. Leaves simple, with stipules.

Group 2.—Achlamydosæ.

Neither calyx nor corolla present.

Alliance 1.—Piperales. *Carpels either solitary, or if more than one quite distinct. Flowers in spikes. Embryo minute in the base of fleshy albumen.*

Order 134.—*Chloranthaceæ*. Flowers hermaphrodite or unisexual. Stamens

lateral; anthers 1-celled, with a fleshy connective. Ovary 1-celled. Ovule pendulous. Fruit drupaceous. Embryo minute at the apex of fleshy albumen. Herbaceous plants. Stems jointed. Leaves opposite with intervening stipules.

Order 135.—*Saururaceæ.* Flowers hermaphrodite. Stamens 6, clavate, persistent. Ovaries 4, distinct; ovules solitary, ascending; or a 3- 4-celled pistil. Nuts 4, indehiscent; or 3- 4-celled capsule. Embryo minute in a fleshy sac, on the outside of hard mealy albumen. Herbaceous marsh or water plants. Leaves alternate with stipules.

Order 136.—*Piperaceæ.* Flowers hermaphrodite. Stamens definite or indefinite. Ovary superior, 1-celled, containing a single erect ovule; stigma sessile, simple. Fruit somewhat fleshy, indehiscent. Seed erect, with the embryo lying in a fleshy sac placed at that end of the seed which is opposite the hilum, on the outside of the albumen. Shrubs or herbaceous plants. Leaves without stipules. Flowers usually sessile in spikes.

Alliance 2.—Salicales. *Flowers amentaceous. Fruit mostly many-seeded. When one-seeded in globular heads.*

Order 137.—*Salicaceæ.* Flowers unisexual, amentaceous. Ovary superior, 1- or 2-celled; ovules numerous, erect. Fruit coriaceous, 1- or 2-celled, 2-valved, many-seeded. Seeds comose; albumen 0. Trees or shrubs. Leaves alternate, simple, with stipules.

Order 138.—*Platanaceæ.* Flowers amentaceous. Stamens single. Ovaries terminated by a thick style, having the stigmatic surface on one side; ovules solitary, or two, suspended. Nuts clavate. Seeds solitary; embryo in the axis of fleshy albumen. Trees or shrubs. Leaves alternate, with scarious sheathing stipules. Catkins round.

Order 139.—*Balsamaceæ.* Catkins unisexual, roundish. Anthers numerous, nearly sessile; ovaries 2-celled, styles 2. Fruit, a kind of cone composed of indurated connected scales, in the cavities of which lie 2-lobed 2-celled capsules. Seeds compressed, membranous, winged. Embryo inverted in the midst of albumen. Tall trees, yielding balsam. Leaves alternate, with glandular serratures. Stipules deciduous.

Alliance 3.—Monimiales. *Flowers within an involucre. Sexes distinct.*

Order 140.— *Monimiaceæ.* Involucre tubular, valvular. Stamens indefinite, covering all the inside of the involucre; anthers bursting longitudinally. Ovaries superior, 1-celled, inclosed within the tube of the involucre; ovule pendulous. Fruit consisting of 1-seeded nuts, enclosed within the enlarged involucre; embryo in the midst of an abundant albumen. Aromatic trees or shrubs. Leaves opposite, without stipules. Flowers axillary in short racemes.

Order 141.—*Atherospermaceæ.* Involucre calyx-like, tubular, divided into segments placed in two rows. Stamens very numerous in the bottom of the involucre; anthers bursting with a valve. Ovaries usually indefinite. Nuts terminated by the persistent styles become feathery. Seed erect; embryo at the base of soft fleshy albumen. Trees. Leaves opposite, without stipules. Flower-heads axillary, solitary.

Alliance 4.—Podostemales. *Flowers solitary. Carpels 2 or 3, combined. Seeds numerous and minute.*

Order 142.—*Podostemaceæ.* Flowers in a membranous lacerated spathe. Stamens hypogynous, 1-00. Ovary 2- 3-celled; ovules numerous, attached to a central placenta. Fruit capsular; seeds numerous, minute. Herbs growing under water, with capillary leaves and inconspicuous flowers; or with leaves and stem confounded in one leafy expansion.

Alliance 5.—Callitrichales. *Carpels several, combined, single-seeded. Floating plants.*

Order 143.—*Callitrichaceæ.* Flowers unisexual, with 2 fistular bracts. Stamens single; anthers 1-celled. Ovary solitary, 4-cornered, 4-celled; ovules solitary, peltate. Fruit 4-celled, 4-seeded, indehiscent; embryo inverted in the axis of fleshy albumen. Aquatic herbaceous plants, with opposite, simple leaves. Flowers very minute.

Group 3.—Tubiferosæ.

Calyx tubular, often resembling a corolla. Ovary usually single. Embryo never curved round albumen.

Alliance 1.—Santalales. *Calyx adherent to the ovary. Anthers opening by longitudinal fissures.*

Order 144.—*Santalaceæ.* Calyx half-coloured, valvate. Stamens 4-5 inserted in the base of the calyx. Ovary 1-celled. Ovules 1-4 pendulous from the top of a central placenta. Style single. Fruit 1-seeded, indehiscent. Embryo in the axis of albumen. Trees, shrubs, or herbaceous plants. Leaves alternate, without stipules. Flowers small.

Alliance 2.—Daphnales. *Calyx inferior, with an imbricated æstivation. Carpel solitary. Anthers opening by longitudinal fissures.*

Order 145.—*Elæagnaceæ.* Males: calyx 4-parted; stamens 3 to 8, sessile. Female: calyx inferior, tubular, persistent. Ovary 1-celled; ovule ascending; stigma subulate. Fruit enclosed within the calyx; embryo surrounded by fleshy albumen. Trees or shrubs with a scurfy surface. Leaves entire, without stipules. Flowers axillary, often fragrant.

Order 146.—*Thymelaceæ.* Calyx inferior, tubular, coloured. Stamens definite, in the orifice of its tube. Ovary with one pendulous ovule. Fruit nut-like or drupaceous. Albumen none, or thin; embryo straight; radicle superior. Stem shrubby. Leaves without stipules.

Order 147.—*Hernandiaceæ.* Flowers monœcious, with a calycine involucre to the females. Calyx petaloid, inferior, 4-8-parted. Stamens definite in two rows. Ovary 1-celled; ovule pendulous; stigma peltate. Embryo inverted without albumen. Trees. Leaves alternate.

Order 148.—*Aquilariaceæ.* Calyx tubular, 5-cleft, with bearded scales. Stamens 10 or 5. Ovary superior 1-celled; ovules two suspended; stigma large, simple. Capsule 1-celled, 2-valved. Seeds one on each placenta with a tail-like aril; albumen 0; radicle superior. Trees. Leaves alternate without stipules.

Alliance 3.—Proteales. *Calyx valvate. Stamens opposite its lobes. Fruit simple, follicular.*

Order 149.—*Proteaceæ.* Calyx valvular. Stamens 4, opposite the segments of the calyx. Ovary superior; style simple; stigma undivided. Fruit dehiscent or indehiscent. Seed without albumen. Shrubs or small trees. Leaves hard, dry, without stipules.

Alliance 4.—Laureales. *Anthers opening by valves. Carpels solitary, superior or inferior.*

Order 150.—*Lauraceæ.* Calyx 4-6-cleft, imbricated. Stamens definite, perigynous; anthers 2-4-celled, bursting by a valve. Glands at the base of the inner filaments. Ovary superior with one or two pendulous ovules. Fruit baccate. Seed without albumen; embryo inverted. Trees. Leaves without stipules, alternate.

Order 151.—*Illigeraceæ.* Calyx adherent to the ovary; the border divided in two rows, valvular. Stamens in the top of the tube, furnished at the base with glands. Anthers 2-celled, opening by a valve. Ovary inferior, 1-celled; ovule pendulous; stigma peltate. Fruit indehiscent, seed without albumen; cotyledons twisted.

Order 152.—*Cassythaceæ.* Stem dodder-like, leafless. Stamens 9, without glands; anthers 4-celled. Caryopsis included in the berried perianth.

Alliance 5.—Penæales. *Carpels several. Calyx imbricated or valvate.*

Order 153.—*Penæaceæ.* Calyx inferior with bracts at its base, hypocrateriform, limb valvate or imbricated. Stamens either 4 or 8. Ovary superior, 4-celled. Fruit capsular 4-celled. Seed with a nucleus or solid fleshy mass, with no distinction of albumen or embryo. Shrubs. Leaves opposite, imbricated, without stipules.

Group 4.—Columnosæ.

Stamens usually monadelphous, and ovary 3-6-celled; or the latter with an inferior ovary. Wood, without concentric zones.

Alliance 1.—Nepenthales. *Spiral vessels between wood and bark. Diœcious. Ovary superior.*

Order 154.—*Nepenthaceæ*. Diœcious. Calyx inferior. Stamens in a column; anthers opening externally. Ovary superior, 4-cornered, 4-celled; stigma sessile. Fruit capsular, with the seeds sticking to the sides of the dissepiments. Seeds indefinite, minute; fusiform. Embryo in the midst of fleshy albumen. Herbaceous or half-shrubby plants. Leaves alternate, with a dilated foliaceous petiole, pitcher-shaped at end. Stem without concentric zones.

Alliance 2.—Aristolochiales. *Ovary inferior.*

Order 155.—*Aristolochiaceæ*. Hermaphrodite. Calyx superior, valvate Stamens epigynous. Ovary inferior, 3- or 6-celled; style simple; stigmas radiating. Fruit 3- or 6-celled, many-seeded. Seeds with a minute embryo in the base of fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, often with leafy stipules. Wood without concentric zones. Flowers brown, or some dull colour.

Group 5.—Curvembryosæ.

Embryo curved round albumen, or having the form of a horse-shoe, or spiral; calyx rarely tubular, sometimes long and petaloid.

Alliance 1.—Chenopodiales. *Albumen present. Radicle next the hilum.*

Order 156.—*Amarantaceæ*. Calyx scarious persistent, immersed in dry coloured bracts. Stamens hypogynous. Ovary superior, 1 or few-seeded; ovules hanging from a free central funiculus. Fruit a utricle. Seeds lentiform; albumen farinaceous; embryo curved round the circumference; radicle next the hilum. Herbs or shrubs. Leaves simple, without stipules. Flowers in heads or spikes, usually coloured.

Order 157.—*Chenopodiaceæ*. Calyx sometimes tubular at the base, persistent. Stamens inserted into the base of the calyx, opposite its segments. Ovary superior, with a single ovule attached to the base of the cavity. Fruit membranous. Embryo curved round farinaceous albumen, or spiral, or doubled together without albumen. Herbaceous plants or under-shrubs. Leaves alternate without stipules. Flowers small.

Order 158.—*Tetragoniaceæ*. Like the last, but ovary consisting of several cells.

Order 159.—*Phytolaccaceæ*. Calyx of 4 or 5 petaloid leaves. Stamens indefinite, or if equal to the number of the divisions of the calyx alternate with them. Ovary of from 1 to several cells, each containing 1 ascending ovule. Fruit baccate or dry, 1 or many-celled. Seeds solitary, with a cylindrical embryo curved round mealy albumen. Under-shrubs or herbaceous plants. Leaves alternate, without stipules, often with pellucid dots.

Alliance 2.—Polygonales. *Albumen present. Radicle at the end of the embryo most remote from the hilum.*

Order 160.—*Polygonaceæ*. Calyx inferior, imbricated. Stamens definite. Ovary superior, with a single erect ovule. Nut triangular. Seed with farinaceous albumen; embryo inverted; radicle remote from the hilum. Herbaceous plants, rarely shrubs. Leaves alternate, their stipules cohering in the form of an ochrea.

Alliance 3.—Petiveriales. *Albumen absent. Cotyledons spiral.*

Order 161.—*Petiveriaceæ*. Calyx of several distinct leaves. Stamens perigynous, indefinite, or if equal to the segments of the calyx, alternate. Ovary superior 1-celled; ovule erect. Fruit 1-celled, indehiscent, dry. Seed without albumen; radicle inferior. Under-shrubs or herbaceous plants, with an alliaceous odour. Leaves alternate, with distinct stipules, often with minute pellucid dots.

Alliance 4.—Sclerales. *Tube of the calyx hardened.*

Order 162.—*Scleranthaceæ.* Hermaphrodite. Calyx 4 or 5-toothed. Stamens from 1 to 10. Ovary simple, superior, 1-seeded. Fruit a utricle inclosed within the hardened calyx. Seed pendulous from a funiculus; embryo cylindrical, curved round farinaceous albumen. Small herbs. Leaves opposite, without stipules. Flowers axillary, sessile.

Order 163.—*Nyctaginaceæ.* Calyx tubular, somewhat coloured; becoming indurated at the base. Stamens definite, hypogynous. Ovary superior, with a single erect ovule. Fruit a utricle, enclosed within the base of the calyx; embryo with foliaceous cotyledons, wrapping round floury albumen. Stem either herbaceous, shrubby, or arborescent. Leaves opposite, and almost always unequal; sometimes alternate. Flowers having an enclosure which is either common or proper.

Alliance 5.—Cocculales. *Albumen present. Flowers formed upon a ternary plan, with the divisions of the calyx in two rows.*

Order 164.—*Menispermaceæ.* Flowers unisexual, usually very small. Sepals in one or several rows. Stamens monadelphous or distinct. Anthers turned outwards. Ovaries numerous, each with one style, sometimes soldered together into a many-celled body; which is occasionally in consequence of abortion; 1-celled. Drupes berried, 1-seeded; embryo curved lying in albumen; radicle superior. Shrubs with a sarmentaceous habit. Leaves alternate. Flowers small.

Sub-order.—*Lardizabaleæ.* Carpels many-seeded. Leaves compound.

Sub-class III.—MONOPETALÆ.

Group 1.—Polycarposæ.

Ovary of several carpels either combined or distinct.

Alliance 1.—Brexiales. *Albumen absent. Carpels* 5. *Sterile stamens between the fertile ones. Seeds indefinite.*

Order 165.—*Brexiaceæ.* Calyx inferior, 5-parted. Petals 5, hypogynous, imbricated. Stamens 5, hypogynous, from a cup, toothed between each stamen. Ovary 5-celled, ovules attached in two rows to the axis; style 1. Fruit drupaceous; albumen 0. Trees, with nearly simple trunks. Leaves coriaceous, alternate, with stipules.

Alliance 2.—Ericales. *Anthers opening by pores, hard and dry, often with appendages. Carpels from* 4 *to* 5 *or more.*

Order 166.—*Pyrolaceæ.* Calyx 4-5-leaved, inferior. Corolla regular, 4-5-parted. Stamens hypogynous; anthers opening by pores. Ovary 4-5-celled; style declinate; stigma indusiate. Fruit capsular, many-seeded. Seeds winged. Embryo minute, at the base of fleshy albumen. Usually herbaceous plants. Leaves simple.

Order 167.—*Monotropaceæ.* The same as Pyrolaceæ, except, style straight; anthers bursting longitudinally; embryo minute, at the apex of fleshy albumen; stems leafless, or nearly so, but covered with fleshy scales. Parasitical plants.

Order 168.—*Ericaceæ.* Calyx 4 or 5-cleft, inferior. Corolla hypogynous, 4- or 5-cleft, imbricated. Stamens definite, hypogynous; anthers 2-celled, dehiscing by a pore. Ovary many-celled, many-seeded; style 1. Fruit capsular. Seeds indefinite, minute; embryo in the axis of albumen. Shrubs or under shrubs. Leaves evergreen, rigid, without stipules.

Order 169.—*Vaccinaceæ.* In all things like the last, but ovary inferior.

Order 170.—*Epacridaceæ.* Same as Ericaceæ, but anthers 1-celled, and opening longitudinally.

Alliance 3.—Primulales. *Anthers bursting longitudinally without appendages. Carpels* 4-5. *Fruit often* 1-*celled.*

Order 171.—*Primulaceæ.* Calyx 4-5-cleft, persistent. Corolla regular. Stamens inserted upon the corolla opposite its segments. Ovary 1-celled;

style 1; stigma capitate. Capsule with a central placenta. Embryo lying across the hilum in fleshy albumen. Herbaceous plants.

Order 172.—*Myrsinaceæ.* Calyx 4- or 5-cleft. Corolla hypogynous. Stamens opposite the segments of the corolla; filaments distinct, sometimes 5, sterile, petaloid. Ovary 1 with a free central placenta, style 1. Fruit fleshy, mostly 1-seeded. Seeds peltate; albumen horny; embryo lying across the hilum. Trees or shrubs. Leaves alternate, serrated, coriaceous; stipules wanting.

Order 173.—*Sapotaceæ.* Calyx regular, persistent. Corolla hypogynous, its segments usually equal in number to those of the calyx, seldom twice or thrice as many. Stamens arising from the corolla, definite. Anthers usually turned outward; sterile stamens. Ovary with several cells, 1 erect ovule. Style 1. Fruit baccate. Seeds nut-like. Testa bony, shining. Embryo large, usually in fleshy albumen. Trees or shrubs. Leaves alternate, without stipules, coriaceous.

Order 174.—*Ebenaceæ.* Calyx in 3 or 6 divisions. Corolla hypogynous, usually pubescent, imbricated. Stamens definite; twice as many as the segments of the corolla, four times as many, or the same number. Ovary several-celled, the cells having 1 or 2 ovules, pendulous; style divided. Fruit fleshy, few-seeded. Albumen cartilaginous; embryo in the axis; radicle turned towards the hilum. Trees or shrubs without milk. Leaves alternate, coriaceous.

Sub-order.—Styraceæ. Ovary inferior. Stamens perigynous. Style simple.

Order 175.—*Aquifoliaceæ.* Sepals 4 to 6, imbricated. Corolla hypogynous. Stamens alternate with its segments. Disk none. Ovary with from 2 to 6 cells; ovules solitary, pendulous. Fruit indehiscent, with from 2 to 6 stones. Seed suspended; albumen large; embryo small, 2-lobed. Trees or shrubs. Leaves coriaceous. Flowers small.

Alliance 4.—Nolanales. *Fruit divided into distinct lobes.*

Order 176.—*Nolanaceæ.* Calyx 5-parted. Corolla plaited, usually thickened in the tube. Stamens alternate with the segments of the corolla. Pistil several carpels, either distinct, or partially combined; style single. Stigma capitate. Fruit enclosed in the calyx; pericarp woody. Seeds ascending, solitary; embryo curved, with a small quantity of albumen. Herbaceous, or suffruticose plants. Leaves alternate, without stipules.

Alliance 5.—Volvales. *Carpels* 2-4, *combined. Anthers never opening by pores.*

Order 177.—*Convolvulaceæ.* Calyx persistent, in 5 divisions, remarkably imbricated, often unequal. Corolla hypogynous, plaited. Stamens 5, inserted into the base of the corolla. Ovary with 2 or 4 cells; few seeded; ovules erect; style 1. Disk annular. Capsule with the valves fitting at their edges to the angles of a loose dissepiment. Seeds with mucilaginous albumen; embryo curved; cotyledons shrivelled. Herbaceous plants or shrubs, usually twining and milky. Leaves alternate.

Order 178.—*Cuscutaceæ.* Calyx persistent, 4- 5-parted, imbricated. Corolla persistent, imbricated. Scales alternating with segments of corolla; stamens opposite the last. Ovary 2-celled; ovules in pairs erect; styles 2. Capsule. Embryo spiral, acotyledonous, in fleshy albumen. Leafless parasites.

Order 179.—*Polemoniaceæ.* Calyx 5-parted. Corolla regular, 5-lobed. Stamens 5, unequal, on the tube of the corolla. Ovary 3-celled; stigma 3-lobed. Capsule 3-celled; 3-valved, the valves separating from the axis. Embryo in the axis of horny albumen. Herbaceous plants. Leaves opposite.

Order 180.—*Diapensiaceæ.* Calyx of 5 sepals, which are much imbricated. Corolla regular, imbricated. Stamens arising from the margin of the corolla; anthers 2-celled, with a broad connective, bursting transversely. Disk 0. Ovary 3-celled; style single. Capsule membranous. Seeds peltate. Embryo slender, lying across the hilum in fleshy albumen. Under-shrubs, with small imbricated leaves.

Order 181.—*Hydroleaceæ.* Calyx 5-parted, slightly imbricated. Corolla regular. Stamens from between the lobes of the corolla, regular; anthers with a narrow connective. Ovary 2- or 3-celled; styles 2 or 3. Fruit capsular, enclosed in the calyx. Seeds indefinite, very small; albumen fleshy; embryo orthotropous. Herbaceous plants, or under-shrubs. Leaves alternate, with stipules.

Group 2,—Epigynosæ.

Ovary inferior, usually with an epigynous disk; composed of two or more carpels. Anthers never bursting by pores. Stamens always inserted into the corolla.

Alliance 1.—Campanales. *Stipules absent. Seeds indefinite in number.*

Order 182.—*Lobeliaceæ*. Calyx 5-lobed, or entire. Corolla irregular, 5-lobed, or 5-cleft. Stamens 5; anthers cohering. Stigma fringed. Fruit capsular, 1- or more celled, many-seeded; embryo in the axis of albumen. Herbaceous plants or shrubs. Leaves alternate, without stipules.

Order 183.—*Campanulaceæ*. Calyx persistent. Corolla usually 5-lobed, withering, regular, valvate. Stamens alternate with the lobes of the corolla. Anthers distinct. Stigma naked. Fruit dehiscing by apertures, or valves. Seeds numerous; embryo in the axis of albumen. Herbaceous plants or under-shrubs, yielding a white milk. Leaves alternate, without stipules.

Sub-order ?—Sphenocleaceæ. Corolla 5-parted, inflexed. Stamens 5 in the recesses of the corolla. Ovary 2-celled. Capsule circumscissile; embryo without albumen. Flowers minute.

Order 184?—*Belvisiaceæ*. Calyx persistent. Corolla plaited, many-lobed, deciduous. Stamens definite or indefinite. Stigma lobed. Fruit berried, many-seeded. Shrubs. Leaves alternate, entire, without stipules.

Order 185.—*Columelliaceæ*. Calyx 5-parted. Corolla 5-8-parted, imbricated. Stamens 2; anthers 3-lobed, sinuous. Stigma capitate. Disk epigynous, fleshy. Fruit 2-celled, many-seeded. Shrubs or trees. Leaves opposite, without stipules.

Order 186.—*Stylidiaceæ*. Calyx 2-6-parted, permanent. Corolla irregular, imbricated. Stamens 2, connate into an elastic slender column, with which the style is consolidated. Ovary 2-celled. Capsule 2-valved, many-seeded. Seeds albuminous. Glandular herbs.

Alliance 2.—Goodeniales. *Stigma with an indusium.*

Order 187.—*Goodeniaceæ*. Calyx equal, or unequal. Corolla more or less irregular, split at the back; the segments folded inwards in æstivation. Stamens 5, distinct. Ovary with indefinite ovules; stigma surrounded by a membranous cup. Fruit a capsule; albumen fleshy. Herbaceous plants, rarely shrubs, without milk. Leaves scattered, without stipules.

Order 188.—*Scævolaceæ*. Calyx sometimes obsolete. Corolla irregular, split at the back, the edges of the divisions folded inwards in æstivation. Stamens 5, distinct; anthers distinct or united. Ovary few-celled, with solitary erect ovules; stigma surrounded by a cup. Fruit drupaceous or nucamentaceous. Herbaceous plants with the flowers axillary or terminal and never in heads.

Alliance 3.—Cinchonales. *Stipules between the leaves.*

Order 189.—*Cinchonaceæ*. Calyx simple. Corolla tubular, regular, valvate or imbricated. Stamens all on the same line. Ovary surmounted by a disk; ovules numerous or few. Fruit either splitting, or indehiscent and dry, or succulent. Seeds definite or indefinite; embryo small, surrounded by horny albumen. Trees, shrubs, or herbs. Leaves simple, opposite or verticillate, with interpetiolary stipules.

Order 190.—*Lygodysodeaceæ*. In all things Cinchonaceous, except, ovary 1-celled, with 2 ovules. Pericarp brittle, 1-celled. Placentæ 2, free. Seeds 2, pendulous from the apex of the placentæ. Albumen 0. Twining shrubs. Stipules single between the petioles.

Alliance 4.—Capriales. *Stipules wanting. Leaves opposite. Seeds definite.*

Order 191.—*Caprifoliaceæ*. Calyx 4-5-cleft, with bracts at its base. Corolla monopetalous or polypetalous, rotate or tubular, regular or irregular. Stamens epipetalous. Ovary with from 1 to 3 or 4 cells. Fruit indehiscent, 1 or more celled. Embryo straight in fleshy albumen. Shrubs or herbaceous plants, with opposite leaves, destitute of stipules.

Alliance 5.—Stellales. *Fruit didymous. Leaves whorled without stipules. Stem angular.*

Order 192.—*Galiaceæ*, or *Stellatæ*. Calyx 4- 5- or 6-lobed. Corolla rotate or tubular, regular. Stamens equal in number to the lobes of the corolla. Ovary 2-celled; ovules solitary, erect. Fruit a didymous, indehiscent pericarp. Embryo straight in horny albumen. Herbaceous plants, with whorled leaves, destitute of stipules. Angular stems.

Group 3.—Aggregosæ.

Only one perfect carpel present.

Alliance 1.—Asterales *or* Compositæ. *Anthers syngenesious. Flowers in heads surrounded by an involucre.*

Order 193.—*Calyceraceæ*. Albumen present; seed pendulous.

Order 194.—*Mutisiaceæ*. Albumen absent; seed erect. Corolla bilabiate.

Order 195.—*Cichoraceæ*. Albumen absent; seed erect. Corolla ligulate, or 1-lipped. Juice milky.

Order 196.—*Asteraceæ* or *Corymbiferæ*. Albumen absent; seed erect. Involucre hemispherical. Florets of the ray ligulate if present.

Order 197.—*Cynaraceæ* or *Cynarocephalæ*. Albumen absent; seed erect. Involucre rigid or spiny, conical.

Alliance 2.—Dipsales. *Anthers distinct. Ovary inferior.*

Order 198.—*Dipsaceæ*. Calyx superior, membranous; surrounded by an involucel. Corolla oblique, imbricated. Stamens 4; anthers distinct. Ovary 1-celled with a pendulous ovule; stigma simple. Fruit crowned by the pappus-like calyx; embryo in fleshy albumen. Herbaceous plants or under-shrubs. Leaves opposite or whorled. Flowers surrounded by a many-leaved involucre.

Order 199.—*Valerianaceæ*. Calyx superior, membranous, or resembling pappus. Corolla tubular, regular or irregular, sometimes calcarate. Stamens 1 to 5. Ovary with 1 perfect cell, and 2 other abortive ones; ovule pendulous; stigmas 1 to 3. Fruit dry. Embryo destitute of albumen. Herbs. Leaves opposite, without stipules. Flowers corymbose, panicled, or in heads.

Alliance 3.—Brunoniales. *Style single. Stigma with an indusium. Flowers in heads.*

Order 200.—*Brunoniaceæ*. Calyx inferior, with bracts at the base. Corolla almost regular, 5-parted. Stamens definite, hypogynous; anthers slightly cohering. Ovary 1-celled with an erect ovule; stigma in a cup. Fruit membranous, enclosed within the indurated tube of the calyx. Seed without albumen. Herbaceous plants. Leaves radical, with no stipules.

Alliance 4.—Plantales. *Flowers on scapes. Style single. Stigma naked. Ovary superior. Flowers in heads, or spikes, or panicles.*

Order 201.—*Plantaginaceæ*. Calyx 4-parted. Corolla membranous, hypogynous, 4-parted. Stamens 4; filaments flaccid; anthers versatile. Ovary without a disk; ovules peltate or erect, solitary, twin, or indefinite; stigma hispid, simple. Capsule membranous. Embryo in fleshy albumen. Herbaceous plants, with spiked inconspicuous flowers.

Order 202.—*Globulariaceæ*. Calyx persistent, 5-cleft, sometimes 2-lipped. Corolla hypogynous, bilabiate, made up of 5 parts. Stamens 4, from the tube of the corolla. Ovary superior, 1-celled, with a pendulous ovule. Albumen fleshy. Shrubs or herbs. Leaves alternate. Flowers in heads.

Order 203.—*Salvadoraceæ*. Calyx inferior, 4-leaved. Corolla 4-parted. Stamens connecting the petals. Ovary superior, 1-celled, with a sessile stigma; ovule erect. Embryo amygdaloid, without albumen. Shrubs. Leaves opposite. Flowers minute.

Alliance 5.—Plumbales. *Styles 5. Flowers quinary. Ovary superior.*

Order 204.—*Plumbaginaceæ*. Calyx tubular, plaited. Corolla regular. Stamens definite. Ovary superior, 1-seeded; ovule pendulous, from an umbilical

cord; styles 5. Fruit a utricle. Seed inverted. Herbaceous plants, or shrubs. Leaves alternate, undivided, somewhat sheathing.

Group 4.—Nucamentosæ.

Fruit consisting of 4 bony lobes, which are either originally distinct, or which become distinct more or less when fully ripe, or which are separable into little nuts. If capsular, inflorescence gyrate.

Alliance 1.—Phaceliales. *Fruit capsular. Inflorescence gyrate.*

Order 205.—*Hydrophyllaceæ.* Calyx 5-cleft, with reflexed appendages. Corolla regular. Stamens 5, epipetalous. Ovary simple, 1-celled; placentæ 2. Fruit 2-valved. Seeds reticulated; embryo cartilaginous. Herbaceous plants. Leaves usually lobed.

Alliance 2.—Echiales. *Fruit nucamentaceous. Inflorescence gyrate. Flowers symmetrical.*

Order 206.—*Cordiaceæ.* Calyx 5-toothed. Corolla regular. Stamens alternate with the segments of the corolla. Ovary 4-celled, with 1 pendulous ovule in each cell; stigma 4-cleft. Fruit drupaceous, 4-celled. Seed pendulous by a funiculus; cotyledons plaited; albumen 0. Trees. Leaves scabrous, without stipules.

Order 207.—*Ehretiaceæ.* Calyx 5-parted, imbricated. Corolla tubular, imbricated. Stamens from the bottom of the tube. Ovary in an annular disk, 2- or more celled; stigma simple; ovules suspended. Seed solitary; embryo in thin albumen. Trees or shrubs, with harsh pubescence. Leaves alternate, without stipules.

Order 208.—*Boraginaceæ.* Calyx persistent. Corolla hypogynous, regular. Stamens upon the petals, equal to the lobes of the corolla. Ovary 4-parted, 4-seeded; style simple; stigma simple or bifid. Nuts 4, distinct. Seed without albumen. Herbaceous plants or shrubs. Stems round. Leaves alternate, covered with asperities.

Alliance 3.—Labiales. *Fruit nucamentaceous. Inflorescence terminal or axillary. Flowers unsymmetrical, often didynamous.*

Order 209.—*Lamiaceæ* or *Labiatæ.* Calyx tubular, persistent. Corolla bilabiate. Stamens didynamous, the 2 upper sometimes wanting. Ovary 4-lobed; style 1; stigma bifid. Fruit 1 to 4 small nuts. Seeds with no albumen. Herbaceous plants or under-shrubs. Stem 4-cornered. Leaves opposite, replete with aromatic oil. Flowers in axillary cymes; sometimes solitary.

Order 210.—*Verbenaceæ.* Calyx tubular. Corolla irregular. Stamens didynamous, occasionally 2. Ovary 2- or 4-celled; ovules erect or pendulous; style 1; stigma bifid. Fruit composed of 2 or 4 nucules in a state of adhesion; albumen none. Trees or shrubs, sometimes herbaceous plants. Leaves opposite, without stipules. Flowers in opposite corymbs, or spiked alternately; sometimes in dense heads.

Order 211.—*Myoporaceæ.* Calyx 5-parted. Corolla tubular, nearly equal or 2-lipped. Stamens didynamous. Ovary 2-4-celled; ovules pendulous. Fruit a 2-4-celled drupe. Seeds albuminous. Shrubs with little hairiness. Flowers axillary, without bracts.

Order 212.—*Selaginaceæ.* Calyx tubular, rarely of two sepals. Corolla tubular, hypogynous, more or less irregular. Stamens usually didynamous, seldom 2; anthers 1-celled. Ovary superior, very minute. Disk fleshy. Fruit 2-celled, the cells 1-seeded, membranous. Seed pendulous; embryo in fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, often fascicled. Flowers sessile, spiked, with large bracts.

Order 213.—*Stilbaceæ.* Calyx tubular. Corolla hypogynous, somewhat 2-lipped, valvate. Stamens inserted into the top of the tube of the corolla, the upper one always rudimentary, or obliterated; anthers 2-celled. Ovary superior, 2-celled; ovule erect; stigma simple. Disk 0. Fruit 1-seeded surrounded by the calyx. Leaves whorled, narrow, rigid, without stipules. Flowers in dense spikes.

Group 5.—Dicarposæ.

Carpels 2, capsular, with a distinct central placenta; never nucamentaceous. Flowers never gyrate.

Alliance 1. — Bignoniales. *Flowers unsymmetrical, usually didynamous. Seeds often with wings or tail-like processes. Albumen* 0. *Stalks of the seeds never hooked.*

Order 214.—*Pedaliaceæ.* Calyx of 5 pieces. Corolla irregular; rather valvate. Disk hypogynous fleshy. Stamens didynamous. Ovary 1- or 2-celled, sometimes with spurious cells; stigma 2-lobed. Fruit hard and woody or membranous. Seeds not winged; albumen none. Herbaceous plants with nearly opposite leaves. Flowers each with two bracts.

Order 215.—*Bignoniaceæ.* Calyx sometimes spathaceous. Corolla irregular. Stamens 5, of which 1 always and sometimes 3 are sterile. Ovary in a disk, 2-celled, polyspermous; style 1; stigma of 2 plates. Capsule 2-valved, 2-celled, long and compressed. Seeds often winged; albumen 0. Trees or shrubs, often twining or climbing. Leaves opposite, compound, without stipules.

Order 216.—*Cyrtandraceæ.* Calyx campanulate, equal. Corolla irregular, imbricated. Stamens didynamous. Disk annular. Ovary 1-celled, with 2 double placentæ; stigma 2-lobed. Fruit capsular and siliquose, or succulent, many-seeded. Seeds minute, often with little tails; albumen absent. Herbs. Leaves opposite, often radical. Flowers showy, in umbels.

Alliance 2.—Acanthales. *Flowers usually didynamous. Seeds adhering to hard hook-like processes. Albumen* 0. *Calyx as if in more whorls than one; often enveloped in bracts.*

Order 217.—*Acanthaceæ.* Calyx very much imbricated, persistent. Corolla irregular, 2-lipped. Stamens mostly 2. Ovary in a disk, 2-celled, 2 or many-seeded; stigma 2-lobed. Capsule 2-celled, bursting elastically. Seeds hanging by processes of the placentæ, hard, usually hooked; albumen none. Herbaceous plants or shrubs. Leaves opposite, without stipules. Inflorescence in spikes, racemes, fascicles, or even solitary. Flowers usually opposite placed in bracts.

Alliance 3.—Lentibales. *Flowers unsymmetrical, diandrous. Fruit with a free central placenta. Marsh or water plants.*

Order 218.—*Lentibulaceæ.* Calyx persistent, inferior. Corolla irregular, bilabiate, with a spur. Stamens 2; anthers simple. Ovary 1-celled; stigma bilabiate. Capsule 1-celled. Seeds minute, without albumen. Herbaceous plants. Leaves undivided, or resembling roots, and bearing vesicles. Flowers single, or in spikes.

Alliance 4.—Scrophulales. *Flowers diandrous, or didynamous. Seeds with the embryo in albumen; their stalks never hooked. Fruit capsular; placenta parallel with the axis.*

Order 219.—*Gesneraceæ.* Calyx half superior, valvate. Corolla tubular, with an imbricate æstivation. Anthers cohering with a thick connective. Ovary 1-celled, with two 2-lobed polyspermous placentæ; surrounded by glands; stigma capitate. Embryo in the axis of albumen. Herbaceous plants or undershrubs. Leaves opposite, rugose, without stipules.

Order 220.—*Orobanchaceæ.* Calyx permanent. Corolla irregular. Stamens didynamous. Ovary 1-celled, in a fleshy disk, with 2 or 4 parietal placentæ; stigma 2-lobed. Fruit capsular, many-seeded, enclosed within the withered permanent corolla; seeds very minute; embryo extremely small, in the apex of fleshy albumen. Parasitical brown leafless herbs.

Order 221.—*Scrophulariaceæ.* Calyx tubular, permanent. Corolla irregular. Stamens didynamous or 2. Ovary 2-celled; ovules numerous; stigma 2-lobed. Fruit 2-celled; seeds indefinite or definite, albuminous. Herbs or shrubs with opposite or alternate exstipulate leaves.

Alliance 5.—Solanales. *Flowers symmetrical. Placenta parallel with the axis. Embryo lying in albumen.*

Order 222.—*Solanaceæ*. Calyx persistent, inferior. Corolla regular, or somewhat unequal, plaited. Stamens inserted upon the corolla. Ovary 2-celled; stigma simple. Pericarp with 2, or 4, or many cells. Seeds numerous; embryo in fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, sometimes collateral. Inflorescence often out of the axil; pedicels without bracts.

Order 223.—*Cestraceæ*. Same as Solanaceæ, but corolla valvate, embryo straight, cotyledons foliaceous.

Alliance 6.—Gentianales. *Flowers symmetrical, usually tetrandrous or pentandrous. Placenta perpendicular to the axis. Seeds often winged or comose. Leaves opposite.*

Order 224.—*Gentianaceæ*. Calyx inferior, persistent. Corolla regular, with an imbricated twisted æstivation. Stamens inserted upon the corolla, some of them occasionally abortive. Ovary 1- or 2-celled; stigmas 1 or 2. Capsule or berry many-seeded; the margins of the valves turned inwards. Embryo in the axis of soft albumen. Herbaceous plants. Leaves opposite, entire, without stipules, 3-5-ribbed.

Order 225.—*Spigeliaceæ*. Calyx inferior. Corolla regular, valvate. Stamens 5. Ovary 2-celled; style articulated with it. Fruit 2-celled, 2-valved, the valves turned in at the margin. Seeds several; embryo very minute, in fleshy albumen. Herbaceous plants or under-shrubs. Leaves opposite, with stipules.

Order 226.—*Apocynaceæ*. Calyx persistent. Corolla regular, 5-lobed, contorted. Stamens 5. Filaments distinct. Pollen granular. Ovaries 2, or 1- 2-celled, polyspermous. Stigma 1. Fruit double, or single. Seeds with fleshy albumen. Trees or shrubs, usually milky. Leaves opposite, quite entire, often having glands upon the petioles, with no stipules.

Order 227.—*Asclepiadaceæ*. Calyx persistent. Corolla 5-lobed, regular, imbricated, very seldom valvular. Stamens 5. Filaments connate. Anthers 2-celled. Pollen cohering in masses, and sticking to 5 processes of the stigma. Ovaries 2. Styles 2. Stigma common to both styles, 5-cornered. Follicles 2. Seeds comose; albumen thin. Shrubs or herbaceous plants, milky, and often twining. Leaves entire, opposite, having ciliæ between their petioles.

Alliance 7.—Loganiales. *Flowers unsymmetrical. Stamens never* 2. *Leaves always opposite.*

Order 228.—*Loganiaceæ*. Calyx 5-parted. Corolla regular or irregular, convolute. Stamens all upon the same line, 5-1. Stigma simple. Fruit either capsular with placentæ becoming loose; or drupaceous. Seeds peltate, sometimes winged; albumen fleshy or cartilaginous. Shrubs, herbaceous plants, or trees. Leaves opposite, usually with stipules in the form of interpetiolary sheaths.

Order 229.—*Potaliaceæ*. Calyx with 4, 5, or 6 partitions. Corolla regular, with 5 to 10 divisions; æstivation contorted. Stamens all upon the same line. Stigma simple. Fruit succulent, with from 2 to 4 cells. Seeds numerous, peltate: embryo in cartilaginous albumen. Trees or shrubs, quite smooth. Leaves opposite, united by interpetiolar stipules.

Alliance 8.—Oleales. *Flowers regular, unsymmetrical, diandrous.*

Order 230.—*Oleaceæ*. Calyx monophyllous, persistent. Corolla hypogynous, 4-cleft, valvate. Stamens 2. Ovary without any disk, 2-celled; ovules pendulous; stigma bifid or undivided. Fruit often by abortion, 1-seeded. Seeds with dense albumen. Trees or shrubs. Branches usually dichotomous. Leaves opposite.

Order 231.—*Jasminaceæ*. Calyx divided or toothed, persistent. Corolla regular, with from 5 to 8 divisions, imbricated and twisted. Stamens 2. Ovary destitute of a disk, 2-celled; ovules erect; stigma 2-lobed. Seeds with no albumen. Shrubs. Leaves opposite or alternate, mostly compound.

Class II.—GYMNOSPERMS.

Exogens, with their ovules exposed naked to the fertilizing influence of the pollen.

Order 232.—*Gnetaceæ.* Flowers monœcious or dicœcious, in catkins or heads. Males; calyx 1-leaved; filament simple or branched; one or several anthers, opening by a pore. Females naked; ovary perforated at the apex, containing a solitary erect ovule, pointed by a style-like process. Fruit drupaceous. Pericarp leathery or shelly. Embryo dicotyledonous, in the middle of fleshy albumen. Small trees, or sarmentose shrubs, with thickened separable articulations. Leaves opposite, entire, with pinnate veins, sometimes very minute. Ligneous tissue marked with circular disks.

Order 233.—*Cycadaceæ.* Flowers dicœcious. Males monandrous, in cones. Females either in cones, or in the form of contracted leaves. Ovules solitary, naked. Embryo in the midst of albumen. Trees, with a cylindrical trunk, increasing by a single terminal bud. Leaves pinnated, gyrate.

Order 234.—*Pinaceæ*, or *Coniferæ.* Flowers monœcious or dicœcious. Males monandrous or monadelphous, collected in a deciduous amentum. Females in cones. Ovary a flat scale. Ovule naked. Fruit a cone. Seed with a hard integument. Embryo in oily albumen, with 2 or many opposite cotyledons. Trees or shrubs, with a branched trunk abounding in resin. Ligneous tissue marked with circular disks. Leaves entire.

Order 235.—*Taxaceæ.* Flowers monœcious or dicœcious, solitary. Filaments monadelphous. Females; ovules naked, their outer skin becoming hard. Seed hard, either naked or surrounded by a succulent cup. Albumen fleshy. Embryo dicotyledonous. Trees with continuous branches. Ligneous tissue marked with circular disks. Leaves usually entire; sometimes dilated and lobed, and in those cases having forked veins.

Order 236.—*Equisetaceæ.* Inflorescence consisting of peltate scales. Flowers in the inside of the lobes of the scales. Stamens 4, clavate, wrapped round a naked ovule. Leafless branched plants with a striated fistular stem; the articulations separable and surrounded by a toothed sheath. Spiral vessels very few.

Class III. ENDOGENS, OR MONOCOTYLEDONS.

Elementary organs consisting of both cellular and vascular tissue, a portion of the latter being elastic spiral vessels. Trunk increasing in diameter by the addition of new matter to the centre. Leaves not readily separated from the stem by an articulation, with parallel simple veins, connected by smaller transverse ones. Propagation effected by stamens and pistils. Ovules in a pericarp. Embryo with but 1 cotyledon; if 2, then one imperfect, and alternate with the other.

Group 1. Epigynosæ.

Anthers distinct. Flowers complete, ternary. Ovary inferior; or if superior, then the leaves either scurfy or equitant.

Alliance 1.—Amomales. *Leaves with the veins diverging from the midrib to the margin.*

Order 237.—*Zingiberaceæ* or *Scitamineæ.* Calyx superior, tubular. Corolla irregular, with 6 segments in 2 whorls. Stamens 3, of which the 2 lateral are abortive. Filament not petaloid. Anther 2-celled. Stigma dilated, hollow. Fruit usually capsular, occasionally berried. Seeds with or without an aril; albumen floury; embryo enclosed within a vitellus. Aromatic, tropical, herbaceous plants.

Order 238.—*Marantaceæ.* Calyx superior, of 3 sepals. Corolla irregular, with the segments in 2 whorls. Stamens 3, petaloid, of which one of the laterals and

the intermediate are barren or abortive. Filament petaloid. Anther 1-celled. Stigma cucullate, and incurved. Seeds without aril; albumen hard; embryo naked. Herbaceous tropical plants destitute of aroma.

Order 239.—*Musaceæ*. Flowers spathaceous. Perianth 6-parted, petaloid, in 2 rows. Stamens 6, some abortive; anthers 2-celled. Stigma usually 3-lobed. Fruit either a 3-celled capsule, or succulent. Embryo in the axis of mealy albumen. Leaves sheathing at the base, and forming a kind of spurious stem; often very large.

Alliance 2.—Narcissales. *Flowers hexandrous. Sepals and petals petaloid. Leaves never scurfy; with the veins running parallel from the base to the apex.*

Order 240.—*Amaryllidaceæ*. Calyx and corolla regular, colored. Stamens 6; anthers bursting inwardly. Stigma 3-lobed. Albumen fleshy or corneous. Generally bulbous, sometimes fibrous-rooted, occasionally with a cylindrical stem. Leaves ensiform.

Order 241.—*Hæmodoraceæ*. Calyx and corolla more or less woolly. Stamens either 3 and opposite the petals, or 6; anthers bursting inwardly. Stigma undivided. Fruit somewhat nucamentaceous. Leaves equitant.

Order 242.—*Burmanniaceæ*. Perianth tubular, membranous, with 6 teeth the 3 outer, and wing or keel at the back. Stamens 3; anthers sessile, opening transversely. Stigma 3-lobed, petaloid. Capsule covered by the withered perianth. Seeds very numerous, minute. Herbaceous plants, with tufted radical acute leaves, or none; and terminal flowers, sessile upon a 2 or 3-branched rachis, or solitary.

Order 243.—*Taccaceæ*. Perianth with the limb petaloid, equal or unequal. Stamens 6; filaments hooded at the apex; anthers inserted below the points of their filaments. Ovary of 3 connate carpels, with 3 parietal polyspermous placentæ; styles 3, connate; stigmas radiating, 2-lobed. Pericarp 1-celled, many-seeded. Albumen fleshy. Embryo on the outside of the albumen. Large perennial herbs, with a tuberous root. Leaves pedatifid. Flowers on the top of a scape.

Alliance 3.—Ixiales. *Stamens 3, with the anthers turned outwards.*

Order 244.—*Iridaceæ*. Calyx and corolla confounded, sometimes irregular. Stamens 3, from the base of the sepals; anthers bursting externally. Stigmas 3, often petaloid. Albumen corneous, or densely fleshy. Herbaceous plants, or undershrubs. Roots tuberous or fibrous. Leaves equitant.

Alliance 4.—Bromeliales. *Calyx usually calycine, sometimes petaline. Petals petaline. Stamens 6 or more. Albumen mealy.*

Order 245.—*Bromeliaceæ*. Calyx 3-parted, usually herbaceous. Petals coloured. Stamens 6, or more. Stigma 3-lobed, or entire, often twisted. Seeds numerous; embryo taper, or minute, in the base of mealy albumen. Stemless or short-stemmed plants, with rigid channelled leaves often covered with cuticular scales.

Alliance 5.—Hydrales. *Calyx calycine, Petals petaline. Stamens more than 6. Albumen absent.*

Order 246.—*Hydrocharaceæ*. Sepals 3, herbaceous. Petals 3, coloured. Stamens definite or indefinite. Ovary 1 or many-celled; stigmas 3-6; ovules often parietal. Seeds without albumen; embryo undivided, antitropous. Floating or water-plants.

Group 2. Gynandrosæ.

Stamens and style consolidated into a column. Flowers complete, ternary. Ovary inferior.

Order 247.—*Orchidaceæ*. Sepals 3. Petals 3, of which 2 are uppermost, and 1, the lip, undermost. Stamens 3, united in a column, the 2 lateral abortive, the central perfect, or the central abortive, and the 2 lateral perfect; pollen powdery, or cohering in masses. Ovary 1-celled with 3 parietal placentæ;

style a part of the column of the stamens; stigma a viscid space in front of the column. Capsule bursting with 3 or 6 valves. Seeds very numerous; testa loose, reticulated. Herbaceous plants. Leaves often articulated with the stem.

Order 248.—*Vanillaceæ.* Perianth articulated with the ovary, sometimes with an external calycine cup. Sepals 3, of which 1 forms a lip. Stamen 1, pollen granular. Ovary 1-celled, with 3 parietal placentæ. Fruit succulent. Seeds with a smooth testa tightly adhering to them. Herbaceous plants, with broad leaves; stem mostly climbing.

Order 249.—*Apostasiaceæ.* Calyx and corolla of 3 similar pieces. Anthers 2 or 3, upon a short column. Ovary 3-celled, with 3 polyspermous placentæ in the axis; style filiform, with a slightly 3-lobed stigma. Capsule 3-celled, 3-valved. Seeds very minute, with a skin fitting the nucleus, or scobiform. Perennial herbaceous plants. Leaves firm, thin, sheathing at the base.

Group 3. Hypogynosæ.

Flowers colored, in all cases ternary. Ovary superior.

Alliance 1.—Palmales. *Arborescent plants, with stems growing by the development of a central bud; rarely dichotomous. Embryo in no certain position.*

Order 250.—*Palmaceæ.* Flowers hermaphrodite, or polygamous. Perianth 6-parted, persistent. Stamens inserted into the base of the perianth, definite or indefinite. Ovary 3-celled, or deeply 3-lobed, with an erect ovule. Fruit baccate or drupaceous, with fibrous flesh. Albumen cartilaginous; embryo in a cavity at a distance from the hilum. Leaves terminal, very large, pinnate, or flabelliform, plaited in vernation. Spadix enclosed in a valved spatha. Flowers small.

Alliance 2.—Liliales. *Calyx and corolla distinct, both petaloid. Embryo in the axis of albumen.*

Order 251.—*Pontederaceæ.* Perianth tubular, more or less irregular, with a circinate æstivation. Stamens 3 or 6, unequal. Ovary 3-celled, many-seeded; stigma simple. Embryo in the axis of mealy albumen. Aquatic or marsh-plants. Leaves sheathing at the base.

Order 252.—*Melanthaceæ.* Perianth in 6 pieces, or tubular; generally involute. Stamens 6; anthers turned inwards. Ovary 3-celled, many-seeded; style trifid or 3-parted. Capsule divisible into 3 pieces. Albumen dense, fleshy. Roots fibrous, sometimes fascicled. Rhizoma sometimes fleshy. Leaves sheathing at the base.

Order 253.—*Gilliesiaceæ.* Flowers hermaphrodite, surrounded by bracts. Perianth either a single lobe, or an urceolate 6-toothed body. Stamens 6, all fertile, or 3 sterile. Ovary 3-celled; stigma simple. Capsule 3-celled, many-seeded. Seeds with a broad hollow neck; embryo curved in the midst of fleshy albumen. Small herbaceous plants. Flowers inconspicuous.

Order 254.—*Liliaceæ.* Calyx and corolla colored, regular. Stamens 6. Anthers opening inwards. Ovary 3-celled; stigma simple, or 3-lobed. Fruit 3-celled. Embryo in the axis of fleshy albumen. Roots fibrous, or fasciculate. Stem none; a bulb; or tuberous, or creeping, or arborescent.

Alliance 3.—Commelales. *Sepals leafy. Petals colored. Carpels 3, completely combined.*

Order 255.—*Commelinaceæ.* Sepals 3, herbaceous. Petals colored, sometimes cohering at the base. Stamens hypogynous, some deformed. Ovary 3-celled; stigma 1. Capsule 2- or 3-celled. Seeds often twin; embryo pulley-shaped, in a cavity remote from the hilum; albumen fleshy. Herbaceous plants. Leaves usually sheathing.

Alliance 4.—Alismales. *Sepals usually herbaceous. Petals colored. Carpels more or less distinct. Albumen* 0.

Order 256.—*Butomaceæ.* Sepals 3, herbaceous. Petals 3, colored. Stamens definite or indefinite. Ovaries 3, 6, or more. Follicles many-seeded. Seeds

minute, attached to the whole of the inner surface of the fruit. Aquatic plants. Leaves very cellular, often milky.

Order 257.—*Alismaceæ*. Sepals 3, herbaceous. Petals 3, petaloid. Stamens definite or indefinite. Ovaries several, 1-celled; ovules ascending. Fruit not opening, 1 or 2-seeded. Embryo shaped like a horse-shoe. Floating plants.

Alliance 5.—Juncales. *Flowers somewhat glumaceous.*

Order 258.—*Juncaceæ*. Flowers hermaphrodite or unisexual. Calyx and corolla more or less glumaceous. Stamens 6, sometimes 3. Ovary 1- or 3-celled. Stigmas generally 3. Fruit capsular, with 3 valves. Seeds neither black nor crustaceous; albumen firm; embryo within it. Herbaceous plants, with fascicled or fibrous roots. Flowers generally brown or green.

Order 259.—*Philydraceæ*. Perianth 2-leaved, withering. Filaments 3, united at the base; the lateral ones petaloid and sterile; anther with distinct cells. Stigma capitate. Capsule 3-celled, 3-valved. Seeds numerous, minute. Root fascicled, fibrous. Leaves ensiform, equitant. Flowers alternate, solitary, sessile, subtended by a spathaceous bract.

Group 4. Retosæ.

Leaves either with many ribs, the intervals between which are netted, or with a midrib and netted sides; foot-stalk articulated with the stem. Embryo without a lateral slit. Flowers never arranged in a spadix. Floral envelopes complete. Twiners or climbers.

Order 260.—*Smilaceæ*. Flowers hermaphrodite or dicœcious. Calyx and corolla inferior, 6-parted. Stamens 6, seldom hypogynous. Ovary 3-celled; stigmas 3. Fruit a roundish berry. Albumen between fleshy and cartilaginous. Herbaceous plants or under-shrubs, with a tendency to climb. Stems woody.

Order 261.—*Dioscoreaceæ*. Flowers dicœcious. Calyx and corolla superior. Stamens 6. Ovary 3-celled, with 1- or 2-seeded cells; style deeply trifid. Fruit leafy, compressed, occasionally succulent. Embryo small, near the hilum, in a large cavity of cartilaginous albumen. Twining shrubs. Leaves alternate, occasionally opposite.

Order 262.—*Roxburghiaceæ*. Perianth of from 4 to 6 petaloid divisions. Stamens 4 to 6; anthers opening inwards. Ovary superior, 1-celled, with polyspermous placentæ; stigma capitate. Pericarp 1-celled. Seeds with an embryo in the axis of fleshy albumen. Twining shrubs. Flowers large and showy.

Group 5. Spadicosæ.

Flowers imperfect, with scales in the room of calyx and corolla, or naked; in most cases on a spadix within a spathe. Embryo usually with a lateral cleft.

Alliance 1.—Pandales. *Flowers on a spadix. Fruit drupaceous. Leaves rigid and with parallel veins. Stem usually arborescent.*

Order 263.—*Pandanaceæ*. Flowers dicœcious or polygamous, on a wholly covered spadix. Perianth wanting. Filaments with single anthers. Ovaries collected in parcels, 1-celled; stigmas sessile; ovules solitary, erect. Fruit drupes, or berries. Albumen fleshy; embryo not slit. Stem arborescent, usually sending down aërial roots. Leaves imbricated in three rows, with their margins almost always spiny.

Order 264.—*Cyclanthaceæ*. Flowers monœcious or polygamous, spirally arranged. Males consisting of 2 anthers opening longitudinally in 4 lines. Ovaries with a parietal placenta. Fruit berried. Leaves plaited, petiolate. Spathes membranous and colored.

Alliance 2.—Arales. *Flowers on a spadix. Fruit berried or capsular.*

Order 265.—*Araceæ*. Flowers unisexual. Perianth wanting. Stamens definite or indefinite, very short. Ovary 1-celled, very seldom 3-celled; ovules erect, or pendulous, or parietal; stigma sessile. Fruit succulent. Embryo in the axis of albumen, with a cleft in one side. Herbaceous, or shrubby; stemless or arbo-

rescent. Leaves with parallel or branching veins; sometimes compound. Spadix generally enclosed in a spathe.

Order 266.—*Acoraceæ*. Flowers hermaphrodite, surrounded with scales. Spathe leaf-like. Stamens with 2-celled anthers, turned inwards. Ovaries distinct. Fruit finally juiceless. Seeds albuminous. Rhizoma jointed. Leaves ensiform.

Alliance 3.—Typhales. *Flowers on a spadix. Anthers elevate on long filaments. Sepals of the females either* 3, *or a ring of long hairs.*

Order 267.—*Typhaceæ*. Flowers unisexual upon a naked spadix. Sepals 3, sometimes a bundle of hairs. Petals wanting. Stamens 3 or 6; anthers wedge-shaped. Ovary single, 1-celled; ovule pendulous; stigmas 1 or 2, linear. Fruit not opening. Embryo in the centre of albumen, with a cleft in one side. Herbaceous plants, growing in marshes or ditches. Leaves rigid, ensiform.

Alliance 4.—Fluviales. *Flowers in loose spikes, or solitary.*

Order 268.—*Naiadaceæ* or *Fluviales*. Flowers hermaphrodite or unisexual. Perianth of 2 or 4 pieces, rarely wanting. Stamens definite. Ovaries 1 or more; ovule pendulous. Fruit not opening, 1-celled, 1-seeded. Albumen none; embryo antitropous, with a lateral cleft. Water-plants. Leaves very cellular. Flowers inconspicuous.

Order 269.—*Juncaginaceæ*. Sepals and petals both herbaceous, rarely absent. Stamens 6. Ovaries 3 or 6, cohering firmly; ovules 1 or 2, erect. Fruit dry; albumen wanting; embryo orthotropous, with a lateral cleft. Herbaceous bog-plants. Leaves ensiform. Flowers inconspicuous.

Order 270.—*Pistiaceæ*. Flowers 2, naked. Stamens definite. Ovary 1-celled, with erect ovules. Fruit membranous or capsular, 1 or more seeded. Embryo either in the axis of fleshy albumen, and having a lateral cleft, or at the apex of the nucleus. Floating plants, with very cellular, lenticular, or lobed stems and leaves. Flowers from the margin of the stems.

Group 6. Glumosæ.

Perianth usually 0, in its room herbaceous or scarious bracts, imbricated over each other; if present surrounded by such bracts.

Order 271.—*Graminaceæ*. Flowers consisting of imbricated bracts. Glumes usually 2, alternate. Paleæ 2, alternate. Scales 2 or 3, sometimes wanting. Stamens hypogynous, 1, 2, 3, 4, 6, or more; anthers versatile. Ovary simple; styles 2, very rarely 1 or 3; stigmas feathery. Pericarp membranous. Albumen farinaceous; embryo on one side of the albumen, lenticular. Culms cylindrical, usually fistular. Leaves alternate, with a split sheath. Flowers in little locustæ.

Order 272.—*Cyperaceæ*. Flowers consisting of imbricated solitary bracts. Perianth none. Stamens definite, 1, 2, 3, 4, 5, 6, 7, 10, 12; anthers fixed by their base. Ovary often surrounded by bristles; ovule erect; style single, trifid, or bifid. Nut crustaceous or bony. Embryo lenticular, within the base of the albumen. Leaves with their sheaths entire.

Order 273.—*Desvauxiaceæ*. Perianth 0, except sometimes a 2-valved glume. Stamen 1. Ovaries from 3-18. Fruit as many utricles. Little tufted herbs. Leaves setaceous. Flowers in a terminal spathe.

Order 274.—*Restiaceæ*. Perianth inferior, 2-6-parted. Stamens 2-6; anthers usually unilocular. Ovary 1- or more-celled; cells monospermous; ovules pendulous. Fruit capsular, or nucamentaceous. Embryo lenticular, on the outside of the albumen. Herbaceous plants or under-shrubs. Leaves simple, narrow, or none. Culms protected by sheaths which are slit, and have equitant margins. Flowers in spikes.

Sub-order.—*Eriocauleæ*. Flowers in heads. Calyx membranous and very cellular. Seeds covered with hairs. Aquatic plants with cellular equitant leaves.

Order 275.—*Xyridaceæ*. Calyx glumaceous, 3-leaved. Corolla 3-petalled. Fertile stamens 3, upon the claws of the petals; anthers turned outwards. Style

trifid. Capsule 1-celled, 3-valved, with parietal placentæ. Embryo on the outside of the albumen, at the end most remote from the hilum. Herbaceous plants with fibrous roots. Leaves radical, ensiform, with equitant bases. Flowers in terminal, naked, imbricated heads.

Class IV. RHIZANTHS.

Parasitical fungoid leafless plants. Stem homogeneous. Vascular system present. Flowers propagated by sexes. Seeds consisting of a homogeneous sporuliferous mass.

Order 276.—*Rafflesiaceæ*. Flowers by abortion, diœcious. Perianth superior, 5-parted, imbricated; the throat surrounded by calli. Column adhering to the tube of the perianth; anthers numerous, 2-celled, opening by a vertical aperture. Ovary inferior, 1-celled, with many-seeded parietal placentæ; styles conical. Stemless plants. Flowers solitary, immersed among scales.

Order 277.—*Cytinaceæ*. Flowers monœcious at the top of a stalk covered with scales. Perianth tubular, with a spreading limb. Column fleshy, thickened at the point, covered by anthers. Anthers 8, 2-celled. Ovary inferior, 1-celled, with 8 parietal placentæ. Style simple, joined to the tube of the perianth by septiform processes; stigma capitate, thick.

Order 278.—*Balanophoraceæ*. Flowers monœcious, in dense heads. Calyx deeply 3-parted, equal, spreading. Stamens 1-3, epigynous, with both united filaments and anthers; the latter 3. Ovary inferior, 1-2-celled, 1-2-seeded; ovule pendulous. Style 1; stigma simple, rather convex. Fruit 1-celled, containing spores collected in a bag resembling a seed. Fungus-like plants, parasitical upon roots. Stem naked, or covered by imbricated scales.

Order 279.—*Cynomoriaceæ*. Known from Balanophoraceæ by their stamens being distinct, and the perianth of the male flowers imperfect.

Class V. ACROGENS.

Substance of the plant composed of cellular tissue chiefly; spiral vessels or ducts only present in the highest orders. Stem either increasing by an extension of its point, or by a development in all directions from one common point; not increasing in thickness when once formed. Sexual organs absent. Reproduction taking place by spores, or by a mere dissolution of the utricles of tissue.

Alliance 1.—Filicales, *or* Filices. *Leafy plants producing a rhizoma. Leaves usually coiled up in vernation, with dichotomous veins of equal thickness. Thecæ arising from the veins upon the leaves, pedicellate, with an elastic ring, or sessile and destitute of a ring.*

Order 280.—*Polypodiaceæ*. Thecæ with a vertical, usually incomplete ring; bursting irregularly and transversely.

Order 281.—*Gleicheniaceæ*. Thecæ with a transverse, occasionally oblique ring, nearly sessile, and bursting lengthwise internally.

Order 282.—*Osmundaceæ*. Thecæ with an operculiform ring, or without any; reticulated, striated with rays at the apex; bursting lengthwise, and usually externally.

Order 283.—*Dancæaceæ*. Thecæ sessile, without any ring, concrete into multilocular sub-immersed masses, opening at the apex.

Order 284.—*Ophioglossaceæ*. Thecæ single, roundish, coriaceous, opaque, without ring or cellular reticulation, half 2-valved. Vernation straight.

Alliance 2.—Lycopodales. *Stems solid, vascular. Reproductive organs growing on the stem.*

Order 285.—*Lycopodiaceæ*. Moss-like plants, with creeping stems, the axis abounding in annular ducts; or stemless plants, with erect subulate leaves, and a solid cormus. Organs of reproduction axillary sessile thecæ, containing either minute powdery matter, or sporules, marked at the apex with three minute ridges.

Order 286.—*Marsileaceæ*. Creeping plants. Leaves petiolate and divided, coiled up in vernation. Reproductive organs enclosed in leathery involucres, and of two kinds, the one consisting of sacs containing a body or bodies which germinate, the other of similar sacs containing loose granules. Leaves with veins.

Order 287.—*Salviniaceæ*. Stems rooting and floating. Leaves sessile, imbricated, usually papillose. Receptacles globose, of two forms; some filled with angular corpsucles, others 1-celled, comprehending numerous small stalked many-spored bags.

Alliance 3.—Muscales. *Flowerless plants, with a distinct stem having no vascular system, but frequently furnished with leaves; sporules contained in distinct thecæ. Germinating processes uniting into a heterogeneous body.*

Order 288.—*Bryaceæ*, or *Musci*. Cellular plants, having a distinct axis, covered with minute leaves. Reproductive organs of two kinds, viz.: axillary, cylindrical stalked sacs, containing a multitude of particles emitted upon the application of water; and thecæ or hollow urn-like cases, covered by a calyptra, closed by a lid, within which are rows of processes, called the peristome; the centre of the thecæ occupied by a columella. Sporules protruding confervoid filaments, which afterwards ramify, and form an axis.

Order 289.—*Andræaceæ*. Branching moss-like plants, with imbricated leaves. Thecæ with a calyptra, splitting longitudinally into four valves. Persistome 0. Spores attached to a central columella.

Order 290.—*Jungermanniaceæ*. Creeping moss-like plants, either with imbricated leaves, or with the leaves and axis all fused into one. Thecæ without an operculum, 4-parted, or 2-4-valved. Spores mixed with elaters.

Order 291.—*Marchantiaceæ*, or *Hepaticæ*. Plants composed entirely of cellular tissue, emitting roots from their under-side, and consisting of an axis, bordered by a membranous expansion, which sometimes forms a broad lobed thallus. Reproductive organs consisting of a peltate stalked receptacle, bearing thecæ on its under surface; or of sessile naked thecæ, immersed, or superficial.

Alliance 4.—Charales. *Vascular system wholly wanting. Germinating processes uniting into a heterogeneous body. Reproductive organs axillary globules. Tissue tubular.*

Order 292.—*Characeæ*. An axis, consisting of parallel tubes. Organs of reproduction, succulent globules, containing filaments and fluid; and axillary nucules, formed of short tubes, twisted spirally.

Alliance 5.—Fungales. *Flowerless leafless plants, with no distinct axis of growth. Sporules lying naked in the substance of the plant. Germinating processes either wholly distinct or confluent in a homogeneous body.*

Order 293.—*Fungaceæ*, or *Fungi*. Plants consisting of cellules, among which filaments are occasionally intermixed, increasing in size by addition to their inside; their outside undergoing no change after its first formation, frequently ephemeral. Sporules lying either loose among the tissue, or enclosed in sporidia.

Order 294.—*Lichenaceæ*, or *Lichenes*. Perennial plants spreading in the form of a lobed thallus. Reproductive matter of two kinds; 1, sporules lying in membranous tubes, immersed in shields; 2, separated cellules of the medullary layer of the thallus.

Order 295.—*Algaceæ*, or *Algæ*. Leafless flowerless plants, with no distinct axis; growing in water, consisting either of simple vesicles, or of articulated filaments, or of lobed fronds. Reproductive matter either wanting or in the joints of the filaments, or in thecæ of various forms. Sporules in germination elongating in two opposite directions.

We shall conclude our observations upon the natural system by explaining to the reader the best method of studying it, and the real nature of the difficulties attendant upon its application to practice.

It is alleged by those who are more anxious to throw impediments in the way of a student, than to facilitate his progress, that the natural system of Botany is essentially so abstruse, that no one except those whose lives are devoted to the science, can hope to understand it. It is asserted, that in regard to the three great classes of Dicotyledons, Monocotyledons, and Acotyledons, there is rarely an opportunity of ascertaining to which a given plant belongs, because it is so seldom that the seed can be procured, or because it is so difficult to examine when obtained; and hence, although, supposing the point to be ascertained, the labour of searching through 295 orders would be reduced to one third, yet that in practice, in consequence of the preliminary difficulty just alluded to, the distinction into three classes is perfectly nugatory. But it has been already shewn that although those three classes are distinguished by differences in their seeds, yet that the seed does not furnish the only distinctions between them, but that they are known equally well by differences in their flowers, leaves, manner of germination, and usual mode of growth; so that instead of any real difficulty in finding the class of a plant because of the minuteness of its characters, there is rather a difficulty in mistaking it, so numerous and obvious are the distinctions.

But supposing the difficulty, thus shewn to be imaginary, really to occur, still the student ought not to be disheartened at the number of the natural orders being so great as 295, for of those a large proportion consists of plants of unfrequent occurrence or of little importance, and the great bulk of the vegetable kingdom is comprehended in comparatively a small number of orders. This is shewn, so far as flowering plants are concerned, by the following table of the number of species contained in each natural order of the British Flora:—

1	Ranunculaceæ	37	(1) 37
2	Berberaceæ	2	
3	Nymphæaceæ	3	
4	Papaveraceæ, Fumariaceæ	18	(2) 18
5	Brassicaceæ	70	(3) 70
6	Violaceæ	8	
7	Cistaceæ	6	
8	Droseraceæ	3	
9	Frankeniaceæ	2	
10	Polygalaceæ	2	
11	Malvaceæ	6	
12	Hypericaceæ	11	(4) 11
13	Silenaceæ	23	(5) 23
14	Alsinaceæ	37	(6) 37
15	Linaceæ	5	
16	Tiliaceæ	4	
17	Aceraceæ	2	
18	Geraniaceæ	18	(7) 18
19	Oxalidaceæ	2	
20	Balsaminaceæ	1	
21	Illecebraceæ	5	
22	Tamaricaceæ	1	
23	Portulacaceæ	1	
24	Crassulaceæ	16	(8) 16
25	Saxifragaceæ	28	(9) 28
26	Lythraceæ	3	
27	Rhamnaceæ	2	
28	Aquifoliaceæ	1	
29	Celastraceæ	1	
30	Staphyleaceæ	1	
31	Fabaceæ	74	(10) 74
32	Rosaceæ	84	(11) 84
33	Grossulaceæ	6	
34	Onagraceæ	14	(12) 14
35	Circæaceæ	2	
36	Apiaceæ	66	(13) 66
37	Galiaceæ	21	(14) 21
38	Caprifoliaceæ	8	
39	Cornaceæ	3	
40	Loranthaceæ	1	
41	Vaccinaceæ	4	
42	Ericaceæ	14	(15) 14
43	Pyrolaceæ	6	
44	Campanulaceæ	12	(16) 12
45	Lobeliaceæ	3	
46	Valerianaceæ	7	
47	Dipsaceæ	6	
48	Cichoraceæ	37	(17) 37
49	Asteraceæ	66	(18) 66
50	Cynaraceæ	26	(19) 26
51	Boraginaceæ	24	(20) 24
52	Convolvulaceæ	5	
53	Polemoniaceæ	1	
54	Plantaginaceæ	6	
55	Plumbaginaceæ	4	
56	Oleaceæ	3	
57	Apocynaceæ	2	
58	Gentianaceæ	15	(21) 15
59	Solanaceæ	12	(22) 12
60	Primulaceæ	18	(23) 18
61	Lentibulaceæ	7	
62	Scrophulariaceæ	46	(24) 46
63	Orobanchaceæ	8	
64	Verbenaceæ	1	
65	Lamiaceæ	50	(25) 50
66	Santalaceæ	1	
67	Elæagnaceæ	1	

68	Thymelaceæ	2	
69	Polygonaceæ	24 (26) 24	
70	Amarantaceæ	1	
71	Chenopodiaceæ	26 (27) 26	
72	Sclerantnaceæ	2	
73	Urticaceæ	7	
74	Resedaceæ	3	
75	Euphorbiaceæ	16 (28) 16	
76	Empetraceæ	1	
77	Aristolochiaceæ	2	
78	Ulmaceæ	7	
79	Betulaceæ.	4	
80	Salicaceæ.	33 (29) 33	
81	Corylaceæ	6	
82	Pinaceæ	3	
83	Taxaceæ	2	
84	Myricaceæ	1	
85	Callitrichaceæ	3	
86	Araceæ	1	
87	Acoraceæ	1	
88	Typhaceæ	6	
89	Naiadaceæ	15 (30) 15	
90	Pistiaceæ	4	
91	Juncaginaceæ	3	
92	Alismaceæ	6	
93	Hydrocharaceæ	2	
94	Iridaceæ	6	
95	Orchidaceæ	38 (31) 38	
96	Melanthaceæ	2	
97	Amaryllidaceæ	5	
98	Liliaceæ	26 (32) 26	
99	Dioscoreaceæ	1	
100	Butomaceæ	1	
101	Restiaceæ	1	
102	Juncaceæ	31 (33) 31	
103	Cyperaceæ	92 (34) 92	
104	Graminaceæ	125 (35) 125	
		1394 1265	

So that the whole of the British flowering plants is comprehended in 35 natural orders, with the exception of 129 species, which belong to 69 orders.

Dr. Asa Gray has made a similar calculation with reference to the Flora of the United States. He estimates that thirteen sixteenths of North American plants belong to 35 natural orders, in the following proportions:—

Asteraceæ, Cichoraceæ, Cynaraceæ	566
Graminaceæ	330
Cyperaceæ	250
Fabaceæ	236
Rosaceæ	158
Brassicaceæ	136
Scrophulariaceæ	131
Corylaceæ, Salicaceæ, Betulaceæ	120
Lamiaceæ	108
Ericaceæ	108
Ranunculaceæ	107
Apiaceæ	69
Onagraceæ	69
Saxifragaceæ	67
Orchidaceæ	62
Silenaceæ, Alsinaceæ	57
Caprifoliaceæ	53
Euphorbiaceæ	52
Polygonaceæ	57
Gentianaceæ	44
Asclepiadaceæ	43
Galiaceæ, Cinchonaceæ	39
Polemoniaceæ	38
Boraginaceæ	35
Violaceæ	35
Convolvulaceæ	35
Solanaceæ	34
Primulaceæ	31
Pinaceæ, Taxaceæ	31
Chenopodiaceæ	31
Liliaceæ	39
Malvaceæ	28
Juncaceæ	24
Melanthaceæ	24
Polygalaceæ	23

And of these moreover the 9 natural orders at the head of the list include one half of the whole number.

It is therefore obvious that there exists a necessity for the acquaintance with a very small part only of the natural system, in order to possess a knowledge of the systematical relations of the greater part of a given Flora.

The most useful method of becoming familiar with each natural order is to procure some species, no matter which, provided it is typical—generally those belonging to the genus after which the order is named, are the commonest and most characteristic—and to examine and describe it carefully, so as to impress it distinctly upon the mind. Having done this, the student should in the next place compare his description with the account he finds of his plant in the books in his possession; if the two agree, he will of course conclude that he has observed it correctly; but if there should be any discrepancy, he ought then to re-examine his plant, with a view to ascertaining whether he is in error or not. A full acquaintance with the typical species being thus obtained, it will be as well to procure a few other nearly related species and to com-

pare them carefully with the first, for the sake of seeing to what extent a deviation from the organization of the original species takes place in them.

In like manner a second natural order should be studied, then a third, and so on, till several types of structure are made familiar to the mind. If about 30 or 40 different forms are correctly understood upon this plan, the student will possess a key to the systematical arrangement of any European Flora according to natural affinities. He will next proceed to study the distinctive characters of such genera as he meets with in each natural order, and he will find that the facility of examining them will be in proportion to the correctness with which he has possessed himself of the characters proper to the natural orders themselves.

It is only after the student has advanced to this point that he is recommended to engage in the study of the smaller and less important natural orders.

The real difficulties that present themselves to the inexperienced botanist are very different from those which are commonly adduced, and are in fact of precisely the same nature as those which occur in regard to all systematical arrangements whatsoever. They arise out of the very nature of natural history, and are caused by that constant tendency to vary from a typical form, which seems to be an essential property of organic matter. It has already been shewn in this treatise that an exact definition is an impossibility in respect to the distinctions of plants, whether viewed as species, genera, tribes, orders, alliances, or groups; that is to say, that no character can be framed to which an exception may not be produced; or that if particular instances of exactly defined associations of plants can be produced, as of Apiaceæ for instance, the cause of such exceptions to a very general rule may be reasonably referred to the incomplete knowledge of them which we as yet possess; and we are justified by all analogy in anticipating the discovery of exceptions to the characters of all such associations.

For example, the principal part of the genus Rhamnus consists of pentapetalous species; and consequently Rhamnus is stationed among Polypetalous Exogens; but Rhamnus alaternus has no petals, and would therefore be looked upon by a student who attended only to words as an incomplete Exogen. This would necessarily be a source of great embarrassment, and illustrates perfectly the most material difficulty that occurs in systematical Botany. But it is not confined to a natural arrangement; on the contrary, such cases happen quite as frequently in the Linnean artificial arrangement, as is shewn by the same genus Rhamnus. The principal part of this genus consists of species which are hermaphrodite and pentandrous; but Rhamnus catharticus is dicœcious. In consequence of the preponderance of pentandrous hermaphroditism, Rhamnus is placed in Pentandria; but if a student meets with Rhamnus catharticus he will naturally search for it in Dicœcia, where he will not find it. In both these cases, equally, the position of the exceptional species in a system is necessarily determined by their resemblance to other species, and not by their accordance with the verbal definition of the part of the system in which they are placed.

An English botanist has shewn that these cases occur far more frequently than is supposed, in the popular Linnean system. He has proved that in the British Flora alone there are in fourteen sections of the sexual system, containing 173 genera, no fewer than forty-three exceptions, which is nearly equal to one quarter of the whole; (*Lindley's Introduction to the Natural System of Botany*, ed. 1, p. xiii;) and in like manner an ingenious American Botanist has shewn that out of 274 genera belonging to eighteen Linnean sections, there is about the same proportion (78) of exceptions; that is to say, between one-third and one-fourth of the whole number contains "species which are uniformly or commonly at variance with the class or order to which they are referred: thus presenting a much greater amount of exceptions than can be found in all natural families, not only of the district which the work embraces, but in the whole of North America. A similar analysis, compiled from a general Flora of North America according to this system would, we doubt not, exhibit a much greater proportion of exceptions." (*Asa Gray's Elements of Botany*, p. 309.)

Of such instances as that of Rhamnus there is a large number; many polypetalous orders contain monopetalous and incomplete genera, many monopetalous natural orders contain

polypetalous genera, and some even apetalous, as Primulaceæ; and the groups, alliances and genera are in the same condition. Practically such exceptions are not of importance to the experienced botanist, for he soon ceases to judge of plants by their verbal characters, and forms his opinions of them by their natural resemblance in the mass of their characters to other things with which he is acquainted. He knows, for example, that an apetalous Rhamnus is not the less a Rhamnus from wanting petals, *because in all other respects it corresponds with that polypetalous genus.* But the beginner, or the inexperienced botanist, is in a different position; he has not that previous knowledge to refer to, and he is necessarily embarrassed by such exceptions. As these occur perpetually under whatever point of view plants are systematically arranged, it has been proposed to overcome the difficulties they occasion by a method of investigation purely analytical, from which all idea of combination is excluded; for an explanation of which, see chap. xiii.

Chapter X.

Of Artificial Systems.

The sole object proposed by an artificial system is to enable a person to discover the name of a given plant, if it is already known to naturalists. An artificial system may therefore be compared to a dictionary in which words are arranged according to the correspondence of their initial letters, adjacent words having no necessary agreement, except in commencing with the same letters. Such an arrangement of the words of a language is of the highest utility; because from the immutability of words it is impossible for any person to be misled who knows how to spell; and if the nature of plants were immutable in the same degree, an artificial arrangement would also be of great importance in Botany; but it happens that no certain and unvarying signs can be discovered in the vegetable kingdom, and consequently an artificial arrangement participates in all the inconveniences of a natural arrangement, without offering any advantages in compensation. Hence artificial systems are gradually falling into disuse, and are chiefly employed now by writers for popularity.

There are those who conceive that the whole purpose of a systematical arrangement of objects in natural history is to enable a person to discover readily the name of a particular species; and through that discovery to ascertain what is known of its habits, uses, qualities, and so on. Those who entertain that opinion attach little value to a natural arrangement; for the importance of making a systematical classification coincide with an accordance in structure, manner of growth, use, quality, and so on, is in their estimation an object not worth the trouble it appears to occasion.

Let it not, however, be supposed that those great botanists with whom artificial schemes of classification have originated had any such opinion as this. On the contrary, Linnæus in particular invented his system merely as a temporary expedient for reducing disorder into order, and never contemplated its being retained after the principles of the natural system should be better investigated than they had been in his day; and Jussieu applied his merely to the classification of genera too imperfectly known to be correctly referred to any of the natural orders he had proposed. So that neither of these naturalists, and it is not worth mentioning any others with reference to this subject, contemplated the application of their artificial schemes to other than temporary purposes. They were certainly very far from considering them as anything beyond a convenient means of attaining an important end.

We shall give a brief explanation of that of Jussieu, which is little known, and a larger one of the celebrated sexual system of Linnæus.

Chapter XI.

Of the Artificial System of Jussieu.

At the end of his Genera Plantarum, Jussieu arranged upon an artificial plan all those genera, that, from the imperfect manner in which they had been examined, the incompleteness of their descriptions, or the singularity of their structure, were not capable of being referred to any of his natural orders. Among "methodical indexes," as he called all artificial arrangements, Jussieu considered that the best which is most efficient with the least disturbance of natural affinity, and hence he preferred the great features in the method

of Tournefort, derived from differences in the corolla, to those of Linnæus derived from differences in the sexes. But in regard to secondary characters, he considered the differences taken by Tournefort from the form of the corolla, and from the woody and herbaceous condition of the stem, as unimportant; for which he substituted the position of the ovary with regard to the calyx. He further proposed to subdivide his secondary divisions according to the number, &c., of the stamens; thus forming a combination of the methods of Tournefort and Linnæus with an important addition of his own.

The result of such a combination is the following scheme:—

Class 1.—MONOPETALOUS.

Order 1.—Ovary superior.
Linnean subdivisions.

Order 2.—Ovary inferior.
Linnean subdivisions.

Class 2.—POLYPETALOUS.

Order 1.—Ovary superior.
Linnean subdivisions.

Order 2.—Ovary inferior.
Linnean subdivisions.

Class 3.—APETALOUS, HERMAPHRODITE.

Order 1.—Ovary superior.
Linnean subdivisions.

Order 2.—Ovary inferior.
Linnean subdivisions.

Class 4.—APETALOUS, UNISEXUAL.

Order 1.—Ovary superior.
Linnean subdivisions.

Order 2.—Ovary inferior.
Linnean subdivisions.

It is not a little curious that this scheme, which is in every respect so much superior to that of Linnæus, should have attracted so little notice. For facility of reference, and convenient grouping it is far more useful; as a ready means of sorting plants it is infinitely preferable; and as a method of analysis it has the great advantage of breaking up the vegetable kingdom into a much larger number of subdivisions. The Linnean system does not admit at the most of more than 215 final groups, but this artificial scheme of Jussieu may contain considerably more than 1000. The only mode of accounting for its not having been adopted is upon the supposition that those who studied the work of Jussieu did not recognise the necessity of any artificial method whatsoever, and therefore did not adopt his; while those who preferred an artificial method of classification were either contented with that of Linnæus with all its inconveniences, or were unacquainted with that of Jussieu.

Chapter XII.

Of the Linnean or Sexual System

One of the most remarkable discoveries of Linnæus was the existence in all plants of sexes analogous to those of animals. That some plants have sexes was not indeed any discovery of his, for it was an admitted fact in certain cases long before the time of Linnæus; but it was to him that the world owed the proof that that which had been regarded as a special property of particular kinds of plants was an universal property of vegetable nature. It is not surprising then that when pursuing his investigations of this curious subject, he should have been led to adopt the differences in the number, position, proportion, &c. of the sexual organs as the basis of a system of classification. Neither is it to be wondered at that the world should have been so dazzled by the brilliancy of the discovery of sexes in plants, and the ready adaptation of the discovery to purposes of

arrangement, by one of the most clear-headed and skilful systematists that the world has ever produced, as to have failed to perceive, even after the lapse of more than half a century, how much more specious than solid is the whole framework of the famous sexual system. Little indeed was really known of the extent of the vegetable kingdom for more than seventy years after the artificial system of Linnæus was first promulgated; it had generally been considered with reference chiefly to the inconsiderable Flora of Europe, and often of mere corners of Europe, for the great mass of Linnean systematists has always consisted of the writers or compilers of little local Floras. Hence the inapplicability of it with any kind of convenience to the whole vegetable kingdom was not capable of being appreciated, and the numerous exceptions which its advocates could not conceal or diminish were undervalued, and spoken of as if they were likely to be fewer in countries of a more varied and richer vegetation, rather than incalculably more numerous.

Before proceeding to discuss specifically the advantages and disadvantages of this celebrated system, we shall first explain the system itself. Its classes, twenty-four in number, are exclusively founded upon differences in the number, position, proportion, adhesion, &c. of the stamens; the orders or subordinate divisions upon variations principally of the styles, although peculiarities in the stamens are sometimes also employed in distinguishing orders as well as classes. The characters of the classes are as follows:—

Class	I.	Stamen 1	Monandria.
	II.	Stamens 2	Diandria.
	III.	Stamens 3	Triandria.
	IV.	Stamens 4	Tetrandria.
	V.	Stamens 5	Pentandria.
	VI.	Stamens 6	Hexandria.
	VII.	Stamens 7	Heptandria.
	VIII.	Stamens 8	Octandria.
	IX.	Stamens 9	Enneandria.
	X.	Stamens 10	Decandria.
	XI.	Stamens 12—19	Dodecandria.
	XII.	Stamens 20 or more, inserted into the calyx	Icosandria.
	XIII.	Stamens 20 or more, inserted into the receptacle	Polyandria.
	XIV.	Stamens 2 long and 2 short	Didynamia.
	XV.	Stamens 4 long and 2 short	Tetradynamia.
	XVI.	Stamens united by their filaments into a tube	Monadelphia.
	XVII.	Stamens united by their filaments into two parcels	Diadelphia.
	XVIII.	Stamens united by their filaments into several parcels	Polyadelphia.
	XIX.	Stamens united by their anthers into a tube	Syngenesia.
	XX.	Stamens united with the pistil	Gynandria.
	XXI.	Stamens and pistils in separate flowers, but both growing on the same plant	Monœcia.
	XXII.	Stamens and pistils not only in separate flowers, but those flowers situated upon two different plants	Dicœcia.
	XXIII.	Stamens and pistils separate in some flowers, united in others, either on the same plant, or two or three different ones	Polygamia.
	XXIV.	Stamens and pistils either not ascertained, or not to be discovered with any certainty, insomuch that the plants cannot be referred to any of the foregoing classes	Cryptogamia.

The characters of the orders depend upon the number of the styles, or of the stigmas, if there be no style, in the first thirteen classes; such are accordingly named,—

Monogynia	Style 1
Digynia	Styles 2
Trigynia	3
Tetragynia	4
Pentagynia	5
Hexagynia	6
Heptagynia	7

Octogynia	Styles	8
Enneagynia	.	9
Decagynia	.	10
Dodecagynia	.	12
Polygynia	.	more than 12.

In the 14th class, Didynamia, the orders depend upon the nature of the ovary. In *Gymnospermia*, the first order, the ovary is divided into four lobes, from the base of which proceeds a single style, and within each of which is contained a single seed. In *Angiospermia*, the 2nd order, the ovary is not lobed, and is usually two-celled, and many-seeded.

In the 15th class, Tetradynamia, the orders are characterised by the form of the fruit: *Siliquosæ* have a long pod; *Siliculosæ* have a short one.

The orders of the 16th, 17th, and 18th classes, Monadelphia, Diadelphia, and Polyadelphia, depend upon the number of the stamens, and have the same nomenclature as the thirteen first classes.

The orders of Syngenesia are determined by the arrangement of their flowers, and by the sex of their florets: thus—

Polygamia, has flowers crowded together in heads.

1. *Polygamia æqualis*, has each floret hermaphrodite, or furnished with perfect stamens and pistil.

2. *Polygamia superflua*, has the florets of the disk hermaphrodite; those of the ray female only.

3. *Polygamia frustranea*, has the florets of the disk hermaphrodite; those of the ray steril.

4. *Polygamia necessaria*, has the florets of the disk male, of the ray female.

5. *Polygamia segregata*, "has several florets, either simple or compound, but with a proper calyx, included within one common calyx."

Monogamia, has the flowers separate, not crowded in heads. This order is generally abolished by Linnean botanists, but for no good reason.

The orders of the 20th, 21st, and 22nd classes are distinguished by the number, &c. of the stamens;

The two orders of the 23rd class depend upon whether the genera are monœcious or diœcious.

The last class, Cryptogamia, is divided into orders according to the principles of the natural system, namely, 1. Filices; 2. Musci; 3. Hepaticæ; 4. Algæ; 5. Fungi.

Various modifications and alterations of this method have, from time to time, been proposed by different writers; some reducing the whole of Monœcia, Diœcia, and Polygamia to other classes, others combining some of the smaller classes with the larger ones. The late Professor Richard in particular suggested several real improvements; but they now excite so little interest, in consequence of the neglect into which the artificial system has deservedly fallen, that it is not worth enumerating them in this place.

The reader will at once perceive the merits of the sexual system of Linnæus. It is so simple that any body may master it in an hour; the names of its classes and orders generally carry with them their own explanation; the parts upon whose difference the system turns are readily examined; and the whole scheme is so plain as to be intelligible to the meanest capacity. These are its advantages. Its disadvantages much more than counterbalance them.

If it is easy to discover the class and order of a plant in the Linnean system, it is proportionably difficult to ascertain its genus, because each order contains a very large number of genera, usually having no relation to each other, and each of which must consequently form a distinct subject of study. But it is very often impossible to discover even the class and order, because the same genus will comprehend species belonging to different classes and orders, and a genus has only one place in the system; so that it is incorrect to say that the artificial method of Linnæus is the same to Botany as an alphabet is to a language, because it has not and cannot have the same precision. An alphabet is formed upon unerring characters: an artificial system in natural history is necessarily founded upon varying characters. In case the inquirer commits an error in determining the class and order of his plant, he has no means of checking it by taking into account other characters than those by which the class and order are actually settled. Finally, it is necessary to have a plant in flower in order to commence its examination, and it is inconvenient to be compelled to study a plant exclusively in some one state, inasmuch as it must often happen that the plant is not in that state when it is collected.

Upon this subject we have the following additional remarks from Professor Lindley:—

It is now admitted on all hands that the artificial system of Linnæus, which was so important and useful at the time when it was first contrived, is altogether unsuited to the present state of science; and in the latest work that has been published in this country, upon that system, the learned and amiable author is forced to rest his defence of his still following it upon "the facility with which it enables any one, hitherto unpractised in Botany, to arrive at a knowledge of the genus and species of a plant." But if a system of Botany is to be nothing more than a contrivance to help those who will not master the elements of the science, to determine the name of a plant; and if it is really necessary to have a mental rail-road on which such persons may be impelled without any exertion of their own; then indeed the analytical tables of the French are infinitely better contrivances than the sexual system; because if well executed they meet every case and lead with certainty to positive results.

I have, however, been always at issue with the Linnean school of Botany as to their system accomplishing even the little that it pretends to; and if I may be permitted to appeal to my own personal experience of the difficulties of a beginner who is unassisted by a tutor, (and few could have had fewer difficulties to contend against than myself,) I should say that it is totally opposed to such a conclusion. I began with the Linnean system, which I was taught to believe little less than an inspired production; I had plenty of books compiled according to that system to consult, and I was fairly driven to seek refuge in the natural system from the difficulties and inconsistencies of that of Linnæus.

It seems to me that there is a confusion of ideas in what is urged in favour of the Linnean system, and that its theoretical simplicity is mistaken for practical facility of application. That the principles of the Linnean system are clear and simple, and easily remembered, is indisputable; that student indeed must be remarkably dull of apprehension who could not master them in a day. But is its application equally easy? that is the point. When, for example, a specimen of a Monopetalous plant has lost its corolla, or when the stamens or pistils are absent, either accidentally, or constitutionally, as in Diœcious plants, what Linnean botanist can classify the subject of inquiry? Or where a genus comprehends species varying in the number of their stamens, as for instance, Polygonum, Salix, Stellaria, and hundreds of others, who is to say which of the species is to determine the classification of the rest? Or when this point has been settled, how is the student to know what passed in the mind of the botanical systematist? The latter puts a genus into Octandria, because out of ten species, one has constantly, and two occasionally, eight stamens, and he includes in the same class and order all the other species of the genus, although they have five, six, or ten stamens. Suppose the student meets with one of the last, and wishes to ascertain its name by the Linnean system, he will look for it in Pentandria, or Hexandria, or Decandria, where he will not find it. After wasting his time, and exhausting his patience in a vain pursuit, he must abandon the search in utter hopelessness, for there is no other character that he can make use of as a check upon the first. At last some one will tell him that his plant is a Polygonum: he turns to his book, wondering how he could have overlooked it; and he finds Polygonum in Octandria. Should he inquire how this is, he will learn that his species belongs to Octandria, not because it is octandrous, *but because it is so very like other Polygonums, that it cannot be separated from them, and they belong in most cases to Octandria.* This is the unavoidable answer; and what does it really mean, except that it is not in consequence of its accordance with the system that the student's Polygonum is to be discovered, *but in consequence of its natural relation to other Polygonums?* so that it is necessary to understand the natural system to make use of the artificial system! This is no exaggerated case, but one of common occurrence. It is undoubtedly true that in some books such inconvenience is guarded against by special contrivances; but those contrivances form no part of the system.

Granting, however, for argument's sake, that these and other objections are overstated, and that the Linnean system does really facilitate the discovery of the class and order to which a plant belongs, let us next consider what advance towards the determination of the genus and species, or in other words the name of a plant, a student has really made, when the class

and order are ascertained. If this argument were conducted, as in strictness it ought to be, with reference to the whole vegetable kingdom, it would be easy to show that the student had in fact gained almost nothing that was of use to him; but in order to give the friends of the Linnean system every advantage in the discussion, let us see of what use it will be to him in regard to the few hundred plants that grow wild in England. For this purpose take the generic characters in Diandria Monogynia, as stated in Dr. Hooker's British Flora, a work in which the subject is treated with all the skill and perspicuity of which it is susceptible, and in which the Linnean system is seen to the greatest advantage. The characters are these:—

* *Perianth double, inferior, monopetalous, regular.*

1. Ligustrum, *Linn.* Privet.—*Cor.* four-cleft. *Berry* two-celled, with the cells two-seeded.

** *Perianth double, inferior, monopetalous, irregular. Seeds enclosed in a distinct pericarp (Angiospermous).*

2. Veronica, *Linn.* Speedwell.—*Cor.* four-cleft, rotate, lower segment narrower. *Caps.* two-celled.

3. Pinguicula, *Linn.* Butterwort.—*Cal.* two-lipped, upper lip of three, lower of one bifid segment. *Cor.* ringent, spurred. *Germen* globose. *Stigma* large, of two unequal plates or lobes. *Capsule* one-celled, with the seeds attached to a central receptacle.

4. Utricularia, *Linn.* Bladderwort.—*Cal.* two-leaved, equal. *Cor.* personate, spurred. *Stigma* two-lipped. *Caps.* globose, of one cell. *Seeds* fixed to a central receptacle.

*** *Perianth double, inferior, monopetalous, irregular. Seeds four, apparently naked (closely covered by the pericarp. Gymnospermous.)*

5. Lycopus, *Linn.* Gipsey-wort.—*Cal.* tubular, five-cleft. *Cor.* tubular, limb nearly equal, four-cleft, upper segment broader, and notched. *Stam.* distant, simple.

6. Salvia, *Linn.* Sage or Clary.—*Cal.* two-lipped, tubular. *Cor.* labiate, the tube dilated upwards and compressed. *Filaments* with two divaricating branches, one only bearing a perfect single *cell* of an *anther*.

**** *Perianth double, superior.*

7. Circæa, *Linn.* Enchanter's Nightshade.—*Cal.* two-leaved, but united into a short tube at the base. *Cor.* of two petals. *Caps.* two-celled; cells one-seeded.

***** *Perianth single, or none.*

8. Fraxinus, *Linn.* Ash.—*Cal.* 0, or four-cleft. *Cor.* 0, or of four petals. *Caps.* two-celled, two-seeded, compressed and foliaceous at the extremity. *Seeds* solitary, pendulous. (Some flowers without stamens.)

9. Lemna, *Linn.* Duckweed.—*Perianth* single, monophyllous, membranaceous, urceolate. *Fruit* utricular.

10. Cladium, *Schrad.* Twig-rush.—*Perianth* single, glumaceous. *Glumes* of one piece or valve, one-flowered, imbricating; outer ones steril. *Fruit* a nut, with a loose external coat, destitute of bristles at the base.

This extract from the British Flora makes it evident that in determining to what genus a plant belongs a great deal of inquiry beyond the discovery that it has two stamens and one style, is indispensable: "The student must be acquainted with the meaning of many technical terms; he must have his plant in different states of growth; he must procure the fruit; he must examine the interior of that part; in short, he must go through a long and careful examination, which is entirely independent of the sexual system. In other and larger classes, such as Pentandria, Hexandria, Tetradynamia, Syngenesia, Gynandria, and Monœcia, the length and difficulty of such an examination are vastly increased. Now I distinctly assert that there is no difficulty in determining the natural orders of plants greater than that of making out the genera in the Linnean system. In fact it is the very same thing, only with a different result: in the one case it leads to the mere discovery of a name, in the other to the knowledge of a great number of useful and interesting facts, independent of the name."

It is necessary to make these obser-

vations, in consequence of the strong prejudices that people entertain in this country concerning the sexual system, believing it to be the most perfect, the most useful, the most philosophical that has ever been devised for the classification of plants. It is no disrespect to the author of that system, to shew its imperfection and inutility; a philosophical character he never dreamed of claiming for it. An ingenious American botanist has well observed, that no one could be more fully aware of the insufficiency of an artificial system in botany, or could more highly appreciate the advantages of the natural method, than Linnæus himself; and the so-called Linnean botanists, in whose estimate the former system leaves little to be desired, have quite mistaken the views of their great master, and sadly misrepresented his opinions. While he framed an artificial system for the convenient arrangement of plants, justly considering it as the one best adapted for this purpose at that day, and indeed as the only available one in the then existing state of the science; he also gave a sketch of a natural method, explaining the principles on which the latter might be expected to rest, and pronounced the investigation of natural affinities to be the great object of his studies, and the most important part of the science; considering the artificial system as a temporary expedient, which however necessary at that day, would inevitably give place to the system of nature so soon as its fundamental principles should be discovered. It will not be deemed irrelevant to adduce more fully the testimony of Linnæus on this subject; since, in this country at least, the well-deserved fame of that distinguished naturalist is somewhat endangered by the eulogies and injudicious zeal of those who pretend to be his followers and exclusive admirers. Linnæus, with all his partiality for the system he himself invented, affirms that the artificial method is but a substitute for the natural, to which it must in due time give place. The natural method, he also states, is and must be the principal object of the science; the elucidation of which is the first and ultimate aim of botanists: to this end the labour of the greatest botanists should be diligently directed, and the merest fragments of this system should be carefully studied. Though not yet discovered, it is held in high estimation by the wisest botanists, while by the less learned it is thought to be of little consequence. "For a long time," continues Linnæus, "I have laboured to establish it; I have made many discoveries, but have not been able to perfect it; yet while I live I shall continue to labour for its completion. In the mean time I have published what I have been able to discover, and whosoever will resolve the few plants which still remain, shall be my Magnus Apollo. Those are the greatest botanists who are able to correct, augment, and perfect this method; which those who are unqualified should not attempt."

It must now, we think, be conceded on all hands, that the day anticipated by Linnæus has arrived, when the artificial system having effected the object for which it was invented—that of serving as a temporary substitute for a natural system—is no longer needed; that it has, in fact, after accomplishing a great amount of good in its day, given place to another method equally convenient, and infinitely more philosophical as well as useful; and those who perpetuate its existence on account of the alleged facilities which it presents for acquiring a mere knowledge of names, with the least possible expenditure of thought, would do well to consider whether the respect due to the system of Linnæus, viewed in reference to the higher ends for which he himself intended it, be not compromised by permitting its degradation to purposes for which it was not originally designed.

Chapter XIII.

Of Analytical Schemes.

It has already been stated that from the variable nature of organic bodies, there is no possibility of framing exact definitions of the associations into which they are systematically distributed. Moreover, the great number of such associations renders it desirable that some ready means should be devised for analyzing them, and bringing their points of difference into direct contrast.

For this purpose two methods have been devised; one, which may be called *the tabular*, by Ray; the other, which may be termed *the dichotomous*, by Lamarck. These are both founded upon the common process of analysis which is unconsciously employed by the human mind. In all cases the mental operation by which one thing is distinguished from another, consists in a

continual contrasting of characters. For instance, in a mass of individuals we distinguish one set which is coloured, and another which is colourless; of those that are coloured we distinguish red, black, blue, and green; of the red, some are square, others are round; of the round, some are sculptured on their surface, others are even:—and so we proceed, analyzing the subject by a constant series of contrasts, until we have arrived at the point beyond which no analysis can go.

Ray reduced this to a tabular form. Lamarck represented it by a constant succession of dichotomies or divarications connected with each other by means of numbers. We offer an example of each, applied to the natural orders comprehended in the Flora of Great Britain.

Tabular Analysis of the Natural Orders comprehended in the British Flora, according to the method of Ray.

CLASS I. EXOGENS.

Sub-class 1. POLYPETALÆ.

* Polyandrous. *Stamens more than* 20.

§ *Ovary inferior, or partially so.*

Leaves with stipules	Pomeæ.
Leaves without stipules	Nymphæaceæ.

§§ *Ovary wholly superior.*

Leaves with stipules.	
Carpels more or less distinct, or solitary	Rosaceæ.
Carpels wholly combined into a solid pistil with more placentas than one.	
Calyx imbricated	Cistaceæ.
Calyx valvate.	
Stamens monadelphous	Malvaceæ.
Stamens distinct	Tiliaceæ.
Leaves without stipules.	
Carpels more or less distinct.	
Stamens perigynous	Rosaceæ.
Stamens hypogynous.	
Calyx in a perfect whorl	Ranunculaceæ.
Calyx in a broken whorl	Hypericaceæ.
Carpels wholly combined.	
Placentas parietal	Papaveraceæ.
Placentas spread over the dissepiments	Nymphæaceæ.
Placentas in the axis	Cistaceæ.

** Oligandrous. *Stamens fewer than* 20.

§ *Ovary inferior, or partially so.*

Placentas parietal.	
Flowers unisexual	Cucurbitaceæ.
Flowers hermaphrodite	Grossulaceæ.
Placentas in the axis.	
Flowers in umbels	Apiaceæ.
Flowers not in umbels.	
Fruit many-seeded,	
two-celled	Saxifragaceæ.
four-celled	Onagraceæ.
Fruit few-seeded	Cornaceæ.

§§ Ovary wholly superior.

† Leaves furnished mith stipules.

Carpels distinct.
- Fruit leguminous . . . . . Fabaceæ.
- Fruit drupaceous or capsular . . . . Rosaceæ.

Carpels combined.
- Placentas parietal.
  - Leaves circinate when young . . . . Droseraceæ.
  - Leaves straight when young . . . . Violaceæ.
- Placentas in the axis.
  - Styles distinct to the base.
    - Calyx in a broken whorl . . . . Elatinaceæ.
    - Calyx in a perfect whorl.
      - Petals minute . . . . . Illecebraceæ.
      - Petals conspicuous . . . . . Saxifragaceæ.
  - Styles more or less combined.
    - Gynobasic.
      - Fruit beaked . . . . . Geraniaceæ.
      - Fruit not beaked . . . . Oxalidaceæ.
    - Not Gynobasic.
      - Calyx imbricated . . . . Portulacaceæ.
      - Calyx valvate . . . . . Rhamnaceæ.

†† Leaves without stipules.

Carpels distinct.
- Anthers with recurved valves . . . . Berberaceæ.
- Anthers with longitudinal valves.
  - Carpels each with an hypogynous scale . . Crassulaceæ.
  - Carpels without an hypogynous scale . . . Ranunculaceæ.

Carpels combined.
- Stamens tetradynamous . . . . . Brassicaceæ.
- Stamens not tetradynamous.
  - Placentas parietal.
    - Calyx polysepalous.
      - Albumen large . . . . . Papaveraceæ.
      - Albumen none . . . . . Resedaceæ.
    - Calyx tubular . . . . . Frankeniaceæ.
  - Placentas in the axis.
    - Styles distinct to the base.
      - Calyx in a broken whorl.
        - Stamens polyadelphous . . . . Hypericaceæ.
        - Stamens monadelphous or free . . Linaceæ.
      - Calyx in a perfect whorl.
        - Carpels divaricating at the apex . . . Saxifragaceæ.
        - Carpels not divaricating.
          - Calyx tubular . . . . Silenaceæ.
          - Calyx many-leaved . . . . Alsinaceæ.
    - Styles more or less combined.
      - Calyx in a broken whorl.
        - regular . . . . . Aceraceæ.
        - papilionaceous . . . . . Polygalaceæ.
      - Calyx in a perfect whorl.
        - Anthers opening by pores . . . Ericaceæ.
        - Anthers opening by slits.
          - Flowers unisexual . . . . . Empetraceæ.
          - Flowers hermaphrodite.
            - Calyx tubular . . . . Lythraceæ.
            - Calyx many-leaved.
              - Stamens hypogynous.
                - Brown parasites . . . Monotropaceæ.
                - Green shrubs . . . . Tamaricaceæ.
              - Stamens perigynous . . . Celastraceæ.

Sub-class II. INCOMPLETÆ.

* Achlamydeous. *Neither calyx nor corolla.*

Seeds comose . . . . . Salicaceæ.
Seeds naked.
  Fruit tricoceous . . . . . Euphorbiaceæ.
  Fruit indehiscent.
    Flowers amentaceous . . . . Myricaceæ.
    Flowers solitary . . . . Callitrichaceæ.
    Flowers panicled . . . . Oleaceæ.

** Monochlamydeous. *A calyx present.*

§ *Ovary inferior, or nearly so.*

lowers unisexual.
  Fruit in a cupule . . . . . Corylaceæ.
  Fruit naked . . . . . Cucurbitaceæ.
Flowers hermaphrodite.
  Ovary one-celled. Anther two-celled.
    Embryo straight.
      Albumen none . . . . . Haloragеæ.
      Albumen fleshy . . . . Santalaceæ.
    Embryo curved . . . . . Chenopodiaceæ.
  Ovary one-celled. Anthers many-celled . . Loranthaceæ.
  Ovary more than one-celled . . . . Haloragеæ.

§§ *Ovary superior.*

Leaves with stipules.
  Flowers hermaphrodite.
    Carpels two, combined into a solid pistil . . Ulmaceæ.
    Carpels solitary or quite separate.
      Calyx membranous . . . . Illecebraceæ.
      Calyx firm and herbaceous.
        Styles single . . . . . Sanguisorbaceæ.
        Styles triple . . . . . Polygonaceæ.
  Flowers unisexual.
    Carpels more than one.
      Flowers amentaceous . . . . Betulaceæ.
      Flowers not amentaceous . . . . Euphorbiaceæ.
    Carpels solitary . . . . . Urticaceæ.
Leaves destitute of stipules.
  Flowers unisexual . . . . . Euphorbiaceæ.
  Flowers hermaphrodite.
    Carpels more than one, consolidated.
      Two divaricating carpels . . . . Saxifragaceæ.
        Carpels not divaricating.
          Stamens hypogynous . . . Alsinaceæ.
          Stamens perigynous.
            Fruit one-celled . . . . Primulaceæ.
            Fruit many-celled . . . . Lythraceæ.
    Carpels solitary, or separate
      Carpels several . . . . . Ranunculaceæ.
      Carpels solitary.
        Calyx with a hardened tube . . . Scleranthaceæ.
        Calyx herbaceous.
          Stipules ochreate . . . . Polygonaceæ.
          Stipules 0.
            Ovules pendulous . . . . Thymelaceæ.
            Ovule erect.
              Leaves lepidote . . . . Elæagnaceæ.
              Leaves naked . . . . Chenopodiaceæ.

Sub-class III. MONOPETALÆ.

* *Ovary superior. Flowers regular.*

Ovary four-lobed . . . . . Boraginaceæ.
Ovary entire.
  Carpels 4, 5, or more.
    Anthers opening by pores.
      Herbs . . . . . Pyrolaceæ.
      Shrubs . . . . . Ericaceæ.
    Anthers opening by slits.
      Stamens opposite the segments of the corolla and equal to them in number . . . Primulaceæ.
      Stamens not opposite the segments of the corolla, if the same number.
        Seeds indefinite . . . . Crassulaceæ.
        Seeds definite in number.
          Ovules erect . . . . Convolvulaceæ.
          Ovules pendulous . . . . Aquifoliaceæ.
  Carpels usually three . . . Polemoniaceæ.
  Carpels only two.
    Diandrous . . . . . Oleaceæ.
    Stamens 4 or more.
      Calyx in a broken whorl.
        Leafy twiners . . . . Convolvulaceæ.
        Leafless twining parasites . . . Cuscutaceæ.
      Calyx in a perfect whorl.
        Carpels ⌒ . . . . . Solanaceæ.
        Carpels ( )
          Corolla imbricated . . . . Gentianaceæ.
          Corolla contorted . . . . Apocynaceæ.
  Carpel single.
    Style single . . . . . Plantaginaceæ.
    Styles 5 . . . . . Plumbaginaceæ.

** *Ovary superior. Flowers irregular.*

Ovary four-lobed . . . . . Lamiaceæ.
Ovary entire.
  Fruit nucamentaceous . . . . Verbenaceæ.
  Fruit capsular.
    Capsule, two-celled
      Leafy . . . . . Scrophulariaceæ.
      Brown leafless parasites . . . Orobanchaceæ.
    Capsule, one-celled, with a free central placenta . Lentibulaceæ.

*** *Ovary inferior.*

Carpel solitary.
  Anthers syngenesious . . . . Asterales.
  Anthers free.
    Carpel quite solitary . . . . . Dipsaceæ.
    Carpel with two additional abortive ones . . Valerianaceæ.
Carpels more than one.
  Anthers syngenesious . . . . Lobeliaceæ.
  Anthers free.
    Anthers opening by pores . . . . Vaccinaceæ.
    Anthers opening by slits.
      Seeds indefinite . . . . Campanulaceæ.
      Seeds definite.
        Leaves whorled . . . . . Galiaceæ.
        Leaves opposite . . . . . Caprifoliaceæ.

CLASS II. GYMNOSPERMS.

Stems without articulations.
- Fruit single . . . . . Taxaceæ.
- Fruit in cones . . . . . Pinaceæ.

Stems articulated . . . . . Equisetaceæ.

CLASS III. ENDOGENS.

* Flowers complete.

§ *Ovary inferior.*

Flowers gynandrous . . . . . Orchidaceæ.

Flowers not gynandrous.
- Stamens 3 . . . . . Iridaceæ.
- Stamens 6 . . . . . Amaryllidaceæ.
- Stamens more than 6 . . . . . Hydrocharaceæ.

§§ *Ovary superior.*

Sepals calycine or glumaceous.
- Carpels consolidated . . . . . Juncaceæ.
- Carpels separate . . . . . Alismaceæ.

Sepals corolline.
- Carpels separate.
  - Anthers turned outwards . . . . Melanthaceæ.
  - Anthers turned inwards . . . . Butomaceæ.
- Carpels consolidated . . . . . Liliaceæ.

** Flowers incomplete.

Flowers glumaceous.
- Stems hollow . . . . . Graminaceæ.
- Stems solid.
  - Seed erect . . . . . Cyperaceæ.
  - Seed pendulous . . . . . Restiaceæ.

Flowers naked, or with a few verticillate scales, on a spadix.
- Anthers clavate on weak filaments . . . . Typhaceæ.
- Anthers sessile.
  - Gemmation convolute . . . . . Araceæ.
  - Gemmation equitant . . . . . Acoraceæ.

Flowers naked, or with a few verticillate scales, not on a spadix.
- Floaters. Ovules pendulous . . . . Naiadaceæ.
- Terrestrial. Ovules erect . . . . Juncaginaceæ.
- Floaters. Ovules erect . . . . Pistiaceæ.

CLASS IV. RHIZANTHS.

There are none in Great Britain.

CLASS V. ACROGENS.

With a distinct axis of growth; leafy.
- Thecæ seated on the leaves . . . . Filicales.
- Thecæ axillary.
  - Thecæ sessile, two-valved . . . Lycopodiaceæ.
  - Thecæ stalked or valveless.
    - Thecæ valveless, with an operculum . . . Bryaceæ.
    - Thecæ valvate, with an operculum . . Andreaceæ.
    - Thecæ valvate, without an operculum . . . Jungermanniaceæ.

With a distinct axis of growth; leafless . . . Characeæ.

Without a distinct axis of growth.
- Surface with stomates.

Thecæ valvate . . . . . Jungermanniaceæ.
Thecæ valveless . . . . . Marchantiaceæ.
Surface without stomates.
Aquatics . . . . . Algaceæ.
Terrestrial or aerial.
With a superficial thallus . . . Lichenaceæ.
Without a superficial thallus . . . . Fungaceæ.

Dichotomous Analysis of the Natural Orders comprehended in the British Flora; according to the method of Lamarck.

1 Plants with distinct and visible flowers . . 2
Plants without flowers 126

2 Leaves netted, wood in concentric layers . . 3
Leaves straight-veined. Wood not in concentric layers 109

3 Flowers complete 4
Flowers incomplete 53

4 Corolla polypetalous 5
Corolla monopetalous 82

5 Stamens more than twenty . . . 6
Stamens fewer than twenty 17

6 Ovary inferior 7
Ovary superior 8

7 Leaves with stipules . . . . . Pomeæ.
Leaves without stipules . . . . Nymphæaceæ.

8 Leaves with stipules 9
Leaves without stipules 12

9 Carpels more or less distinct . . . Rosaceæ.
Carpels consolidated 10

10 Calyx imbricated . . . . . Cistaceæ.
Calyx valvate 11

11 Stamens monadelphous . . . . Malvaceæ.
Stamens distinct . . . . . Tiliaceæ.

12 Carpels distinct, more or less . . . 13
Carpels consolidated 15

13 Stamens perigynous . . . . . Rosaceæ.
Stamens hypogynous 14

14 Calyx in a perfect whorl . . . . Ranunculaceæ.
Calyx in a broken whorl . . . . Hypericaceæ.

15 Placentas parietal . . . . . Papaveraceæ.
Placentas not parietal 16

16 Placentas spread over the dissepiments . . . Nymphæaceæ.
Placentas in the axis . . . . . Cistaceæ.

17 Ovary inferior 18
Ovary superior 23

18 Placentas parietal 19
Placentas in the axis 20

19 Flowers unisexual . . . . . Cucurbitaceæ.
Flowers hermaphrodite . . . . Grossulaceæ.

20	Flowers in umbels	Apiaceæ.
	Flowers not in umbels	21
21	Fruit few-seeded	Cornaceæ.
	Fruit many-seeded	22
22	Fruit two-celled	Saxifragaceæ.
	Fruit four-celled	Onagraceæ.
23	Leaves stipulate	24
	Leaves exstipulate	34
24	Carpels distinct	25
	Carpels combined	26
25	Fruit leguminous	Fabaceæ.
	Fruit drupaceous or capsular	Rosaceæ.
26	Placentas parietal	27
	Placentas in the axis	28
27	Embryo minute. Leaves circinate	Droseraceæ.
	Embryo nearly as long as seed. Leaves straight	Violaceæ.
28	Styles distinct to the base	29
	Styles combined	31
29	Calyx broken whorled	Elatinaceæ.
	Calyx in a perfect whorl	30
30	Petals minute	Illecebraceæ.
	Petals conspicuous	Saxifragaceæ.
31	Gynobasic	32
	Not gynobasic	33
32	Fruit beaked	Geraniaceæ.
	Fruit not beaked	Oxalidaceæ.
33	Calyx valvate	Rhamnaceæ.
	Calyx imbricated	Portulacaceæ.
34	Carpels distinct	35
	Carpels combined	37
35	Carpels each with an hypogynous scale	Crassulaceæ.
	Carpels without an hypogynous scale	36
36	Anthers with recurved valves	Berberaceæ.
	Anthers with longitudinal valves	Ranunculaceæ.
37	Stamens tetradynamous	Brassicaceæ.
	Stamens not tetradynamous	38
38	Placentæ parietal	39
	Placentæ in the axis	41
39	Calyx tubular	Frankeniaceæ.
	Calyx polysepalous	40
40	Albumen large	Papaveraceæ.
	Albumen none	Resedaceæ.
41	Styles distinct to the base	42
	Styles more or less combined	46
42	Calyx in a broken whorl	43
	Calyx in a perfect whorl	44
43	Stamens polyadelphous	Hypericaceæ.
	Stamens monadelphous, or free	Linaceæ.

44 Carpels divaricating at the apex . . . . Saxifragaceæ.
Carpels not divaricating 45

45 Calyx tubular . . . . . Silenaceæ.
Calyx many-leaved . . . . Alsinaceæ.

46 Calyx in a broken whorl 47
Calyx in a perfect whorl . . . .

47 Calyx regular . . . . . Aceraceæ
Calyx papilionaceous . . . . Polygalaceæ.

48 Anthers opening by pores . . . . Ericaceæ.
Anthers opening by slits 49

49 Flowers unisexual . . . . . Empetraceæ.
Flowers hermaphrodite . . . 50

50 Calyx tubular . . . . . Lythraceæ.
Calyx many-leaved 51

51 Fruit one-celled . . . . . Tamaricaceæ.
Fruit many-celled 52

52 Stamens hypogynous . . . . . Monotropaceæ.
Stamens perigynous . . . . Celastraceæ.

53 Neither calyx nor corolla . . . 54
A calyx present 58

54 Fruit in cones 54*a*
Fruit not in cones 54*b*

54*a* Sexes distinct . . . . . Pinaceæ.
Sexes imperfect (doubtful) . . . . Equisetaceæ.

54*b* Seeds naked, in a pulpy cup . . . Taxaceæ.
Seeds in a capsule 54*c*

54*c* Seeds tufted with hairs . . . Salicaceæ.
Seeds not tufted with hairs 55

55 Fruit tricoccous . . . . . Euphorbiaceæ.
Fruit indehiscent 56

56 Floating herbs . . . . . Callitrichaceæ.
Woody plants 57

57 Fruit berried . . . . . Myricaceæ.
Fruit a key (samara) . . . . Oleaceæ.

58 Ovary inferior 59
Ovary superior 65

59 Flowers unisexual 60
Flowers hermaphrodite 61

60 Fruit cupuliferous . . . . Corylaceæ.
Fruit a fleshy pepo . . . . Cucurbitaceæ.

61 Anthers many-celled . . . . Loranthaceæ.
Anthers two-celled 62

62 Ovary one-celled 63
Ovary many-celled . . . . Halorageæ.

63 Embryo curved . . . Chenopodiaceæ.
Embryo straight 64

64 Albumen none . . . . Halorageæ.
Albumen fleshy . . . . Santalaceæ.

65 Leaves stipulate 66
Leaves exstipulate 72

66 Flowers hermaphrodite 67
Flowers unisexual 70

67 Carpels consolidated . . . . . Ulmaceæ.
Carpels solitary or separate 68

68 Calyx membranous . . . . . Illecebraceæ.
Calyx firm and herbaceous 69

69 Styles single . . . . . Sanguisorbeæ.
Styles triple . . . . . Polygonaceæ.

70 Carpels solitary . . . . . Urticaceæ.
Carpels more than one 71

71 Flowers amentaceous . . . . . Betulaceæ.
Flowers scattered . . . . . Euphorbiaceæ.

72 Flowers unisexual . . . . . Euphorbiaceæ.
Flowers hermaphrodite 73

73 Carpels consolidated 74
Carpels solitary or separate 77

74 Carpels two, divaricating . . . . . Saxifragaceæ.
Carpels not divaricating 75

75 Stamens hypogynous . . . . . Alsinaceæ.
Stamens perigynous 76

76 Fruit one-celled . . . . . Primulaceæ.
Fruit many-celled . . . . . Lythraceæ.

77 Carpels several . . . . . Ranunculaceæ.
Carpels solitary 78

78 Calyx herbaceous 79
Calyx with a hardened tube . . . . . Scleranthaceæ.

79 Stipules ochreate . . . . . Polygonaceæ.
Stipules none 80

80 Ovule pendulous . . . . . Thymelaceæ.
Ovule erect 81

81 Leaves lepidote . . . . . Elæagnaceæ.
Leaves naked . . . . . Chenopodiaceæ.

82 Ovary superior 83
Ovary inferior 102

83 Flowers regular 84
Flowers irregular 98

84 Ovary four-lobed . . . . . Boraginaceæ.
Ovary undivided 85

85 Carpels more than four 86
Carpels three or fewer 91

86 Anthers opening by pores 87
Anthers opening by slits 88

87 Herbaceous plants . . . . . Pyrolaceæ.
Woody plants . . . . . Ericaceæ.

88 A free central placenta . . . . . Primulaceæ.
Fruit two-celled or more 89

89 Seeds indefinite . . . . . Crassulaceæ.
Seeds definite in number 90

90 Ovules erect . . . . . Convolvulaceæ.
Ovules pendulous . . . . . Aquifoliaceæ.

91	Flowers diandrous	Oleaceæ.
	Flowers not diandrous	92
92	Fruit one-celled	93
	Fruit more than one-celled	94
93	Style single	Plantaginaceæ.
	Styles five	Plumbaginaceæ.
94	Calyx in a broken whorl	5
	Calyx in a perfect whorl	96
95	Corolla imbricated	Cuscutaceæ.
	Corolla plaited	Convolvulaceæ.
96	Corolla persistent	Gentianaceæ.
	Corolla deciduous	97
97	Leaves opposite	Apocynaceæ.
	Leaves subalternate	Solanaceæ.
98	Ovary four-lobed	Lamiaceæ.
	Ovary undivided	99
99	Capsule with a free central placenta	Lentibulaceæ.
	Placentas axile or parietal	100
100	Brown leafless parasites	Orobanchaceæ
	Leafy plants	101
101	Fruit indehiscent	Verbenaceæ.
	Fruit dehiscent	Scrophulariaceæ.
102	But one perfect carpel	103
	More than one perfect carpel	105
103	Anthers syngenesious	Asterales.
	Anthers free	104
104	Seeds albuminous	Dipsaceæ.
	Seeds exalbuminous	Valerianaceæ.
105	Anthers syngenesious	Lobeliaceæ.
	Anthers free	106
106	Anthers opening by pores	Vacciniaceæ.
	Anthers opening by slits	107
107	Seeds indefinite	Campanulaceæ.
	Seeds definite	108
108	Leaves whorled	Galiaceæ.
	Leaves opposite	Caprifoliaceæ.
109	Flowers complete	110
	Flowers incomplete	118
110	Ovary inferior	111
	Ovary superior	114
111	Flowers gynandrous	Orchidaceæ.
	Flowers not gynandrous	112
112	Anthers turned outwards	Iridaceæ.
	Anthers turned inwards	113
113	Stamens 6	Amaryllidaceæ.
	Stamens more than 6	Hydrocharaceæ.
114	Sepals calycine or glumaceous	115
	Sepals corolline	116

115 Carpels consolidated . . . . . Juncaceæ.
Carpels separate . . . . . Alismaceæ.

116 Carpels consolidated . . . . . Liliaceæ.
Carpels separate 117

117 Anthers turned outwards . . . . . Melanthaceæ.
Anthers turned inwards . . . . . Butomaceæ.

118 Flowers glumaceous 119
Sepals 0, or verticillate scales . . . 121

119 Embryo external to the albumen . . Graminaceæ.
Embryo enclosed in the albumen . . . 120

120 Seed erect . . . . . Cyperaceæ.
Seed pendulous . . . . . Restiaceæ.

121 Leaves equitant 122
Leaves not equitant 123

122 Anthers on long clavate filaments . . Typhaceæ.
Anthers sessile . . . . . Acoraceæ.

123 Flowers in a spathe . . . . . Araceæ.
Flowers naked 124

124 Terrestrial plants . . . . . Juncaginaceæ
Floating plants 125

125 Ovules pendulous . . . . . Naiadaceæ.
Ovules erect . . . . . Pistiaceæ.

126 With a distinct stem 127
Without a distinct stem 132

127 Leafless . . . . . Characeæ.
Leafy 128

128 Thecæ seated on leaves . . . . . Filicales.
Thecæ axillary 129

129 Thecæ valveless . . . . . Bryaceæ.
Thecæ valvate 130

130 Thecæ with an operculum . . . . Andræaceæ.
Thecæ without an operculum 131

131 Thecæ four-valved . . . . . Jungermanniaceæ.
Thecæ two-valved . . . . . Lycopodiaceæ.

132 Skin with stomates 133
Skin without stomates 134

133 Thecæ valvate . . . . . Jungermanniaceæ.
Thecæ valveless . . . . . Marchantiaceæ.

134 Aquatics . . . . . Algaceæ.
Terrestrial or aerial 135

135 Thallus if any membranous and cellular . . Lichenaceæ.
Thallus if any filamentous . . . . . Fungaceæ.

Part IV.—Descriptive Botany.

Chapter I.

Of the importance of Descriptions.

Next to an accurate knowledge of the nature of plants, of the uses of their different parts, and of the manner of classifying them, is to be ranked the power of placing clearly and distinctly before the eye, a description that will enable a person previously unacquainted with a plant, not only to recognize it when he meets with it, but without seeing it to judge correctly of its exact nature, qualities, and affinities. No one is ever likely to have the leisure to examine personally all the plants that the world contains, but all must trust for the knowledge of a very considerable part of them to the descriptions given by others. If one could examine all known plants for one's self, the human mind would be incapable of retaining any distinct recollection of them, but would necessarily trust to descriptions made at the time of examination. If the number of plants to be studied is comparatively limited, still the minuteness of many of their parts is such as often to render dissection and microscopical investigation indispensable: these operations are tedious and difficult, and it would be exceedingly inconvenient, if it were necessary to go into a new investigation of the structure of a given plant every time that a new question arose as to the composition of its minuter parts: one good and careful description obviates the necessity of this, for it can always be referred to and consulted. Hence the great importance of Botanical descriptions, not only to the public but to Botanists themselves, for their private use. Nothing can in fact supply their place: dried specimens carefully arranged in an herbarium are the best substitute: but they are rather to be looked upon as evidence in aid of descriptions than as a means of supplying their place; and next to these come drawings. The latter, when well executed, are undoubtedly most valuable, and to a certain extent supply the place of descriptions; but it requires a much longer time to make a drawing than a description; very few persons know how to draw *correctly*, and still fewer are able to represent with the pencil with sufficient fidelity, what a description expresses in a few words.

Technical descriptions are, for these reasons, of the most indispensable necessity, and may be considered the very foundation of the systematic knowledge of all Botanists.

Chapter II.

Of popular Descriptions.

But it is to be remarked that however valuable descriptions of plants may be found when they are drawn up correctly and according to the exact rules of science, yet nothing is more perfectly useless than those which are prepared by persons ignorant of Botany; they are like the drawings of plants made by mere artists, more calculated to mislead than to instruct. For this reason, what are often called popular descriptions of plants, are mere misrepresentations, and either carry a false idea of that which they describe, or no idea at all. They may be well enough suited to amuse the ear, but they convey no distinct impression to the mind, even if they are tolerably correct as far as they go; for the purposes of poetry, and of sketching views of nature, they may be well enough suited; but they are like the blotches of red and green, and yellow, *put in* to a picture by a painter: the moment they are critically examined, they cease to produce the effect they are intended for.

Descriptions to be of any real use, must be drawn up with great care; every part of a plant must be either spoken of specifically, or so referred to as to be clearly indicated; the terms that are used must be employed precisely, and in the sense of Botanists; and there must be no misapplication of terms, no mistaking one part for another. To be able to write a description, a person must already be a very good Botanist; not a mere fetch-and-carrier of semibarbarous names, not a mere inventor of new species, not a compiler of the systematic writings of other persons; but thoroughly acquainted with the anatomical and external structure of the whole vegetable world, exactly informed upon the laws of organization,

aware of the relation that one part necessarily bears to another, ready to remark all deviations from normal conformation, and, to a certain extent, in possession of the general nature of systematical arrangements; in short, he must not only know how to observe, or how to describe, but how to estimate the value of what he observes, and to correct by the constant application of the general rules and principles of Botanical science the false observations to which we all are liable. Unless a man feels that he is capable of doing all this, he should not attempt to describe a plant Botanically; if it is necessary that he should make descriptions, the previous remarks will inform him of his deficiencies, and he ought to qualify himself for the task. The great cause of the slow advance of Botany is in no inconsiderable degree to be ascribed to the incompleteness or inaccuracy of Botanical descriptions.

As the only satisfactory mode of illustrating the observations now made, will be to quote examples, we may take, as a striking instance of useless descriptions the following popular account of the tree that yields the aromatic bark called Cassia, in the island of Sumatra; see Marsden's History of that island, 3rd edition, p. 156.

"(1.) The leaves are about four inches long, narrower than the bay (to which tribe it belongs), and more pointed; deep green; smooth surface, and plain edge. (2.) The principal fibres take their rise from the peduncle. (3.) The young leaves are mostly of reddish hue. (4.) The blossoms grow six in number, upon slender footstalks, close to the bottom of the leaf. (5.) They are monopetalous, small, white, stellated in six points. (6.) The stamina are six, with one style, growing from the germen, which stands up in three brownish segments, resembling a cup. The trees grow from fifty to sixty feet high, with large, spreading, horizontal branches, almost as low as the earth."

In this case, which we take in preference, as having been published by a clever man, and one who was something of a naturalist, there is not a particle of information that a Botanist could make use of, as we proceed to shew sentence by sentence.

(1.) Nothing is said of the form of the leaves; we are merely told that they are narrower than those of the bay; but they might be narrower and yet very differently formed: not a word is mentioned concerning the arrangement of the veins, nor is the position of the leaves upon the stem described. It is said indeed that the plant belongs to the same tribe as the bay (namely Lauraceæ), and this would no doubt imply that the leaves are alternate; but then a little further on (sentence 5), the affinity of the plant to the bay is contradicted, by the flowers being called monopetalous.

(2.) It is impossible to understand the meaning of this sentence. What fibres are meant? Strong lateral veins in the leaf resembling the midrib? But this can hardly be: first, because the sentence, by the punctuation, is cut off from what relates to the leaf; and, secondly, because the fibres spoken of are referred to the peduncle, that is to say, to the flower stalk. A good Botanist might guess at the meaning of the passage, but it could only be a guess, and after all might be wrong.

(3.) This is unimportant.

(4.) Vague and unsatisfactory. We are told that the flowers grow *close* to the bottom of the leaf; not at the bottom, but close to it; Do they spring then from the lower part of the petiole, or from the stem above the axilla? Are they single, or do they grow upon the ramifications of a panicle, cyme, corymb, or raceme?

(5.) If the plant belongs, as stated, to the bay tribe, the flowers cannot be monopetalous. If they really are monopetalous, where is the calyx, and what is its nature?

(6.) The style is said to grow from the germen. From what other part could it grow? The germen is said to stand up in three brownish segments, resembling a cup: if so, the plant can have nothing to do with the bay tribe. The position of the stamens, the nature of their dehiscence, and their origin, are all omitted.

Such are the observations that suggest themselves to the Botanist, in merely reading over this description; and they are amply sufficient to show how useless it is. But collateral evidence tells us that what Marsden intended to describe, was the plant called *Cinnamomum nitidum;* and that fact being ascertained, the following has to be added to the criticism upon the description. The calyx is called corolla (5); the stamens are 9, not 6 (6); the

name of germen is applied (6) to three steril stamens, and the germen itself, that is to say the ovary, is overlooked!

Chapter III.

Of careless Descriptions.

If such descriptions as that just mentioned, are scientifically useless, how much worse must those be which proceed from professed Botanists, in whose supposed knowledge and technical skill, one would think that confidence may be reposed! In the works of many of the disciples of Linnæus, the descriptions of plants are so meagre, inaccurate, and unsatisfactory, that to this day they would remain mere Botanical enigmas, if the meaning of the authors had not been determined by other evidence than what they themselves afford. Pre-eminent among such Botanists, stands Thumberg, from whose Flora Japonica we extract the following description of the fructification of a new genus he calls Nigrina:

"Calyx none, except a one-leaved bract. Corolla of four petals. Filaments four, very short; anthers globose, white. Germen superior; style single; stigma .... Fruit unknown; perhaps a capsule."

This is all the information given concerning the fructification of a plant which the author considered undescribed, and of which he saw fresh specimens. Supposing the description to be accurate as far as it goes, it excludes every one of the points which it is most essential to be acquainted with; the origin of the stamens, the dehiscence of the anthers, and their æstivation; the relation of the stamens to the petals, the internal structure of the ovary, the number and adhesion of the ovules, all essential points for consideration,—and the more indispensable because of the absence of the fruit of the plant,—are passed by in silence. But as if to compensate for the omission of what it was necessary to state, irrelevant matter is introduced into this description, brief as it is. The bract is called one-leaved: if the plant had *a* bract, it could be no more than one-leaved; if the reverse, then it would no longer be *a* bract. The anthers are said to be white, but their colour is of no importance. But what is most extraordinary, the description is altogether false. The flowers have neither calyx nor corolla; the filaments are three, not four, and the anthers are not globose, but irregular, ovate, fleshy bodies.

Chapter IV.

Of technical Descriptions.

The observations now made upon faulty descriptions, will have given the reader some idea of the manner in which plants ought *not* to be described. We now proceed to explain how they should be described for practical purposes. In the first place, every point of structure of any importance should be introduced; what is important or not can never be reduced to any fixed standard, but varies according to the nature of the plant in question, and has in all cases to be determined by the Botanist himself. All technical terms should be used in their exact sense, if used at all; and nothing should be overlooked that can in any way tend to elucidate structure. It is not however necessary to be excessively minute, unless in the case of plants that are not only quite unknown, but whose natural affinity is also uncertain. When such a plant is to be described, every part of the organization, microscopic or obvious, should be included, and nothing should be taken for granted as unimportant. But as cases of this kind are hardly likely to come within the experience of those who use such a treatise as this, it is unnecessary to go into such details. It will be sufficient to confine attention to common instances.

Another essential circumstance to attend to is, always to describe the parts of a plant in the following order. 1. Root. 2. Stem. 3. Leaves, and stipules, if any. 4. Inflorescence. 5. Bracts, if any. 6. Calyx. 7. Corolla. 8. Stamens; distinguishing filaments and anthers. 9. Ovary and ovules; style; stigma. 10. Fruit. 11. Seed. By paying attention to this, one always knows in what part of a description to look for information concerning a particular organ; whereas if the different parts were spoken of in a confused manner, one would never be certain whether an organ was described or not, without reading through the whole description.

Keeping in view such rules as these, a Botanist may make his descriptions in two ways, either in a diffuse and

readable, or in a terse and technical manner. To the former there is no objection, where space is unimportant, or where the description is to be read by persons who would be repelled by the stiffness and formality of technical phraseology; the latter would, under such circumstances, be misplaced; but it is nevertheless that which must be generally employed, as may be proved in the following manner:

Let the following be the Botanical description of a Wild Heart'sease (Viola tricolor), drawn up in a popular readable way.

The root of this plant consists of a great number of unequal irregular fibres. The stems first fall prostrate, and then rise up, and are perfectly smooth all over the surface; their form is square, their interior is hollow, and at every place where the leaves are set on, they are a little tumid. The leaves grow upon opposite sides of the stem at tolerably equal distances, one above the other; they have a form between ovate and oblong, have a distinct leaf stalk, and are coarsely cut at their edges in a serrated manner; they are quite destitute of hairiness, and are longer than the stipules which grow at their base. The stipules in colour and texture resemble the leaves; they are cut almost to the middle into a number of narrow lobes, of which the terminal one is much the largest; at the base they are prolonged more on one side than another, in a hastate manner. The beautiful little flowers grow singly from the stem, at the places where it joins the leaves, and they have a nodding position on their peduncle; the latter has a smooth surface, is distinctly angular, curves inwards at the upper end, and has a twist somewhere near its middle. At the upper end of the peduncle grow two small bractlets, resembling fine scales, prolonged at the base into something of a hastate figure. The calyx of this plant consists of five distinct sepals, having the same colour and texture as the leaves; they are of a narrow ovate form, sharp-pointed, quite free from hairs, not in any way lobed or divided, and extended below the point of origin into a flat rounded appendage, which is divided by small toothings at the edge: of the sepals, those which stand next the front of the flower are much the largest. The corolla consists of five petals, which are of unequal size, oblong, with a little stalk at the base, and rounded at the upper end; the two uppermost are larger than the rest, of one uniform purple colour, while the three lower are yellow, with purple lines at the base, and furnished with a little tuft of hair at the bottom of the streaks; the intermediate one of these petals is furnished with a short straight spur at the base. The stamens are five in number, inserted into the line between the base of the ovary and the sepals, not so long as the claws of the petals, and of unequal size; the anthers have no filaments, are of a membranous texture, are fringed with white hairs at the edge, and are extended into a broad brown membranous appendage at the point; those two stamens which stand in front of the flower are longer than the others, and protrude from their base on one side a green slender thread-shaped process, which is introduced into the spur of the front petal of the corolla. The ovary has no adhesion to the sepals, is of a spheroidal form, and contains one single cell; on its inside, the ovules, which are very numerous, grow to thrice broad lines running from the apex to the base of the cavity at equal distances; the ovary is terminated by a style, smooth, thickest at the upper end, bent like the letter S, and bearing at the point a round hollow stigma, through one side of which there is an opening into the interior. The ovary, when ripe, changes to a seed vessel of a dry, cartilaginous consistence, containing one cell, and dividing into three equal spreading ovate-lanceolate valves between the broad lines on which the seeds are inserted, so that when the valves are spread open, the seeds are seen sticking to the middle. The seeds are small, shining, oblong bodies, rather narrow at the lower end, and of a pale brown colour; the point of attachment to the placenta is thickened in a fungus-like manner; from this part there rises a fine elevated line, which terminates in a depressed discoloured round spot, stationed at the top of the seed. In the interior is found an embryo of a deep green colour, quite straight, and having a taper radicle, with thin flattened cotyledons a little rounded at the back. Surrounding the embryo is found a quantity of fleshy brittle albumen, in the very axis of which the embryo is placed.

There is nothing in this to which a Botanist could object, except that certain points are omitted, such as the

æstivation of the calyx and corolla, the dehiscence of the anthers, the form of the pollen, and some other matters of a similar kind. But it is also obvious that if all the 100,000 plants supposed to be known were to be described in this manner, and at this length, the mere descriptions alone would occupy 200 volumes like the present, of 500 pages each. It is therefore indispensable that such descriptions should be shortened: and it will be seen by the following specimen, that the *very same* facts, before occupying 106 lines, may be stated in 43 lines, by the mere omission of verbs, articles, superfluous words, and rendering it rather more technical.

Root fibrous. Stems decumbent, smooth, square, fistular, slightly tumid at the nodes. Leaves alternate, ovate-oblong, petiolate, coarsely serrated, smooth, longer than the stipules; stipules leafy, pinnatifid, half-hastate; terminal lobe much the largest. Flowers solitary, axillary, nodding; peduncles smooth, angular, twisted, incurved at apex. Bractlets two, minute, membranous, sub-hastate near the apex of the peduncle. Sepals five, herbaceous, linear-ovate, acute, smooth, entire at the base, prolonged into a concave, rounded, tooth-letted appendage; the anterior much the largest. Petals five, unequal, oblong, unguiculate, rounded at the apex; the two upper largest, whole coloured, purple; the three lowest yellow with purple streaks, and bearded at base; that in the middle having a short straight spur at the base. Stamens five, hypogynous, shorter than the ungues, alternate with the petals, unequal; anthers sessile, membranous, ciliated, with a broad brown membrane at apex; the two anterior the largest, spurred; their spurs green, subulate, lying in the spur of the corolla. Ovary superior, round, one-celled, with three parietal polyspermous placentæ; style smooth, sigmoid, clavate, as long as the ovary; stigma capitate, hollow, with an oblique foramen on one side. Capsule one-celled, three-valved, with a loculicidal dehiscence; valves ovate-lanceolate, spreading, seminiferous in the middle. Seeds shining, roundish, smooth, pale brown; hilum fungous; raphe elevated; chalaza depressed on the apex. Embryo straight, green, in the axis of fleshy albumen; radicle terete; cotyledons plano-convex.

This last description does not in fact then occupy more than 3-8ths as much space as the first, and yet it comprehends every one of the facts included in the first.

But even the admission of descriptions cut down like the last, would render books infinitely too bulky; and therefore by the introduction of generic and specific characters, they are still further shortened.

Chapter V.

Of Generic and Specific Characters.

It has already been explained that a genus is a collection of species agreeing with each other in certain common features; see p. 139. In reducing descriptions like the last, the whole of those common features are separated as a generic character, and given once only at the beginning of the descriptions of the species, and from the descriptions of the species all such common features are omitted. Thus to pursue the illustration with this same Viola tricolor, the following is abstracted to form the generic character of

Viola.

Leaves alternate. Flowers solitary, axillary. Sepals five, herbaceous, prolonged at the base into an appendage, the anterior much the largest. Petals five, unequal, unguiculate; the two upper largest; the lowest one spurred at the base. Stamens five, hypogynous, shorter than the ungues, alternate with the petals, unequal; anthers sessile, with a broad membrane at the apex; the two anterior the largest, spurred; their spurs lying in the spur of the corolla. Ovary superior, one-celled, with three parietal polyspermous placentæ; style sigmoid, clavate; stigma capitate, hollow, with an oblique foramen on one side. Capsule one-celled, three-valved, with a loculicidal dehiscence; valves seminiferous in the middle. Seeds roundish; hilum fungous; raphe elevated; chalaza depressed on the apex. Embryo straight, green, in the axis of fleshy albumen; radicle terete; cotyledons plano-convex.

All the foregoing being abstracted for a generic character, then the following would be all that would be necessary as a description of

Viola tricolor.

Root fibrous. Stems decumbent,

smooth, square, fistular, slightly tumid at the nodes. Leaves ovate, oblong, petiolate, coarsely serrated, smooth, longer than the stipules; stipules leafy, pinnatifid, half-hastate; terminal lobe much the largest. Flowers nodding, peduncles smooth, angular, twisted, incurved at apex. Bractlets 2, minute, membranous, sub-hastate, near the apex of the peduncle. Sepals linear, ovate, acute, smooth, entire; appendage concave, rounded, toot-hletted. Petals oblong, rounded at the apex, the two upper whole coloured purple, the three lowest yellow, with purple streaks, and bearded at the base. Anthers ciliated; the spurs green, and subulate. Ovary round; style smooth. Seeds shining, smooth, pale brown.

This last process of reduction has brought the description of Viola tricolor from 106 to 20 lines in length, without the omission, in fact, of a single character. Further than this it cannot be reduced, if to remain a description.

But as the number of species known to Botanists is exceedingly great, even such descriptions as the last are found too extensive to be employed in all cases; the older Botanists, therefore, contrived what they called *differential or factitious characters*, to stand in lieu of descriptions. In contrasting a number of species of the same genus, it is obvious that if no other points are to be adverted to than such as will distinguish them from each other, the words required to distinguish such species may be extremely few, and that a description may thus be conveniently exchanged for a mere differential expression; it cannot, however, be altered into one; for it no longer remains a description, but a certain form is substituted for it. In order to prevent these specific characters ever extending into descriptions, Linnæus proposed that they should in no case exceed the extent of twelve Latin words; and he rarely, if ever, deviated from that standard.

Take, for instance, his specific characters in the genus Drosera:

1. D. *rotundifolia.* Scapes from the root. Leaves orbicular.

2. D. *longifolia.* Scapes from the root. Leaves oblong.

3. D. *capensis.* Scapes from the root. Leaves lanceolate.

4. D. *lusitanica.* Scapes from the root. Leaves subulate, convex beneath.

5. D. *cistiflora.* Stem simple, leafy. Leaves lanceolate.

6. D. *indica.* Stem branched, leafy. Leaves linear.

By these few words some of the principal differences between the six Droseras known to Linnæus are plainly expressed; but it is obvious that they are not to be confounded with descriptions.

The plan of specific characters devised by Linnæus has been adopted down to the present day; but it is much to be doubted whether they have not been disadvantageous to Botany, rather than the contrary. If, indeed, a systematic writer could say that he is distinctly acquainted with every species in the world of a given genus, then such differential characters would doubtless be invaluable, as they would help another person to arrive rapidly at a definite conclusion concerning any plant he might have for examination. But this is not the case; and therefore the differential characters only lead to error and misapprehension. For instance, Linnæus assigns to Drosera rotundifolia the character of "scapes from the root," and "leaves orbicular;" and this would be a useful character of the species, if those characters existed nowhere else. But we now know that D. uniflora, pygmæa, and rotundifolia all agree in this character; and consequently it is impossible to tell which of the three Linnæus meant, if we judge only from his specific character. And if we alter the phraseology so as to distinguish these three species from each other to-day, to-morrow may bring us acquainted with other species, which will in like manner render the newly altered differential character nugatory.

For these reasons the specific characters of Linnæus have given rise to endless confusion and doubt, and will continue to do so as long as they are employed, unless they are accompanied by longer descriptions. The present practice seems to be to employ short descriptions, or essential characters, in lieu of differential characters; and this upon the whole may be considered better.

CHAPTER VI.

Of Essential and Natural Characters.

We shall conclude this part of our subject with some observations upon the distinction between descriptions of the essential and natural characters of plants.

An essential character is a descrip-

tion of all those points which the observer supposes to be most important, not only in distinguishing it from all other known plants, but from such as his information concerning allied species induces him to anticipate the discovery of. If applied to a species, it omits all notice of varieties of an accidental and fugitive nature, and is constructed only with reference to general, and not particular circumstances. If applied to a natural order, it neglects variations from the typical structure, and confines itself to the normal organization, or what the describer considers to be so, stating that in brief terms. In short, it is, when applied to genera and species, what modern Botanists call a generic or specific character, and is the usual description given of a natural order in general works. Linnæus rightly considered it to be of great value, but extremely difficult to draw up. It is sometimes called a Diagnosis.

A Natural character, on the other hand, is a complete description of the organization of a given species, genus, or order, including an account of every part, and comprehending every deviation from normal structure, whether habitual or accidental. It can only be drawn up at great length, and from its length is only suited to monographs. It is, however, if well drawn up, of the greatest consequence. Linnæus, who however did not understand it in the modern sense, says, "basis est omnium systematum, generum infallibilis custos, omnique systemati possibili et uno applicabilis." And again, "If the Natural characters of all genera had been detected, the knowledge of plants would be very easy; and it is only to their own loss that many Botanists undervalue them. But they ought to know that no one can be a sound Botanist without an acquaintance with natural characters; for a Botanist must, in the absence of Natural characters, be in continual uncertainty as often as new genera are detected. He who fancies he is acquainted with Botany by the use of mere Essential characters, neglecting the natural ones, only deceives others as well as himself; for al Essential characters must become fallacious as fast as new genera are discovered. Natural characters are the very foundation of genera, which it is impossible to understand without them; and therefore they are, and always will be, the foundation of all knowledge of plants."

Although Linnæus did not, as has already been observed, apply the word Natural character in its modern sense yet these declarations of that distinguished man are quite applicable to such descriptions as are here alluded to. The following descriptions of the important natural order Compositæ, or of what we have called the Group Asterales (p. 182), will illustrate the subject of this discussion, and conclude what it appears necessary to introduce in this place from the subject of Descriptions.

Asterales or Compositæ.

Essential Character.

Corolla monopetalous. Stamens syngenesious. Ovary inferior, one-celled; ovule erect. Seed without albumen.

That is to say, all plants agreeing with this description in all its parts, belong to Asterales.

Natural Character.

Vegetation. Herbs, usually perennial, or shrubs, or more rarely (principally in insular situations), trees, occurring all over the world, and forming about a tenth part of the whole vegetable kingdom. Leaves alternate or opposite, extremely variable in form, lobing, or aspect, always simple, never compound. Stem (when simple) or branches terminated by a head or glomerule. Branches generally corymbose, those in the middle the earliest. Leaves stationed below the heads or glomerules usually different from the rest, and called floral or bracteal, changed into scales sometimes gradually, sometimes abruptly, and then much larger than the scales. Corollas now xanthic, now cyanic in the same head, either homochromous or one-coloured, or heterochromous or two-coloured; when two-coloured the ligulate always cyanic and the tubular xanthic; even when the xanthic tubular corollas become ligulate owing to any monstrosity, they also become cyanic! Proper juice variable, sometimes milky. Taste usually bitter, astringent, and aromatic.

Inflorescence.—Flowers collected into a *head* or *glomerule*. Heads consisting of several florets upon a receptacle or end of a branch, whether flat, or conical, or lengthened; the exterior or outer earliest; the interior by degrees later. Flowers either all hermaphrodite, and then the heads homogamous; or the

exterior neuter or female, the inner hermaphrodite, or male, and the heads then heterogamous; or all in the same plant, either male or female, and then the heads either monœcious, that is, both male and female, or heterocephalous, that is, some male some female, or diœcious; that is, all males or females upon the same plant. Heads either with all the corollas tubular, and then called discoidal, or floscular; or with all the corollas ligulate, and then called ligulate, or formerly, semifloscular; or with the corollas of the margin or ray ligulate, of the centre or disk tubular, and then termed radiant; or all bilabiate, and then falsely discoidal; or ligulate at the margin, and bilabiate in the centre, and then falsely radiant or radiatiform. Discoidal, and falsely discoidal heads have sometimes marginal flowers like the others, but larger, and are then called coroneted (coronata). Involucrum consisting of many scales, in one or several rows, free, or (if in one row) united at the edges; dry, scarious, coriaceous, fleshy, spiny, or leafy, often separated into the scale proper, and its appendage; the rows equal or more usually unequal, imbricated, or calyculate, or variously and somewhat irregularly lengthened. Glomerule consisting of one or few flowered heads, furnished with an involucre proper, densely and variously aggregated, surrounded by a general involucrum, seated on a general receptacle; the flowers of the centre generally the earliest; the exterior later, or flowering in no determinate order. Receptacles of the head either foliaceous, that is, furnished with paleæ resembling the scales of the involucrum, situated at the outer side of each flower, articulated above their base, and in occasional monsters expanded into true leaves; or semipaleaceous, namely, furnished with paleæ towards the outside only; or epaleaceous, or naked; that is altogether destitute of paleæ. In some heads (or perhaps glomerules very closely packed together) the receptacle is called sometimes fimbrilliferous, when each flower is surrounded on all sides with a socket scaly at base, and divided at the edge into irregular plates or bristles; sometimes alveolate when the sockets are shallow and not extended into bristles, but often tooth-letted; or finally, areolate, when a pentagonal area, the rudiment of a socket, bounds the base of each flower. Possibly a receptacle more or less paleaceous designates flowers really spiked, and heads in the proper sense of the word; while the fimbrilliferous or alveolate receptacles indicate heads closely packed together, and, properly speaking, umbellate, the sockets representing the rudiments of an involucrum. To speak more plainly, the heads are arranged upon the plan either of a contracted spike or a contracted umbel.

Fructification.—Calyx monocepalous, adhering to the ovary; the tube sometimes equal to the ovary, sometimes longer; its limb or pappus either altogether deficient, or reduced to a narrow rim, very rarely leafy, or more frequently scarious, entire, toothed, lobed, or breaking up into paleaceous scales, or hair-like bristles; simple, branched, tooth-letted, or feathery; one, two, or many rowed. Corolla monopetalous, inserted into the top of the tube of the calyx, neuramphipetalous, that is, having the petals furnished with two nervures next the margin; whence usually five nervures in the tube (ten united in pairs) stretching from the base to the sinus of the lobes, and ten in the lobes, that is, marginal to each lobe; with the addition here and there of accessory nervures in the middle of the petals, and these in a very few instances being the only ones that are distinguishable. Tube variable in length, extending from the base to the insertion of the filaments. Throat usually distended from the insertion of the filaments, as far as the separation of the lobes; lobes generally five, rarely four, or three, or two; valvate in æstivation, sometimes all equal, sometimes almost equal, or irregular, unequal, or palmate; sometimes bilabiate (or three for the outer lip, two for the inner, or four for the outer, one for the inner); sometimes, in consequence of a fissure carried down the inside, expanded into a five-toothed flat ligula. Stamens five, rarely four, in the female or neuter flowers deficient or rudimentary; filaments alternate, with the lobes of the corolla, and therefore corresponding with the nervures of the tube, adnate to the tube of the corolla, free upwards; either wholly distinct from each other, or combined into a tube, and therefore monadelphous, towards the apex articulated, the upper antheriferous joint standing in place of a connective. Anthers erect, in one row, combined into a tube perforated by the style (syngenesious or synan-

thereous), linear, two-celled, opening inwards by a longitudinal cleft, four-valved, the valve turning outwards, at the apex prolonged into an appendix or wing, varying in form and size in different species, and frequently of a different consistence from the part that bears the pollen ; at the base often extended into two tails of variable length and form. Pollen globose or elliptical, rough or smooth. Ovary monocarpellary, adhering to the calyx, one-seeded. Style taper, or more rarely tumid at the base (and then called bulbous), usually in the male flowers quite simple if present, in the females and hermaphrodites bifid at the end; its arms (or vulgarly stigmas) plane above, convex beneath ; either altogether distinct, or more or less united. Stigmatic glands (stigmas properly speaking) in two rows, situated upon the upper face of the arms of the style, in continuous marginal rows, roughish, more or less prominent or distinct. Collecting hairs of pollen rigid, on the upper part of the style in hermaphrodite flowers, or on its arms at the lower side or apex; in the female flowers neuter, or almost none. Fruit, or achenium, composed of the tube of the calyx, the pericarp and the seedskin, more or less completely combined, and enclosing the embryo. Achenium, therefore, one-celled, one-seeded, articulated with the receptacle, most commonly sessile, more rarely stipitate, having an open space (areola) at its base or side, either beakless or rostrate at the point, surmounted by the pappus already described, terminated by an epigynous disk, surrounding the central nectary, which is continuous with the ovary and style-shaped, or socket-like. Seed fixed by a very short cord to the lowest part of the fruit, erect, attached by the base at the side opposite the cord. Lining of the seedskin (albumen Lessing), thickish, tender, semi-transparent, traversed by a double cord. Embryo erect, straight, exorhizal, dicotyledonous; radicle short, straight ; plumule generally inconspicuous, cotyledons plane, usually rather convex at the back, very rarely curved, sometimes accidentally three in number.

It must be obvious to every one, upon reading the foregoing description, that it is so constructed as to comprehend every kind of structure that Composite plants ever present, and that consequently the working Botanist can tell at once, by glancing his eye over the paragraphs, what the structure and limits of variation are of any particular organ, without undertaking the labour of a long and tedious, or perhaps impossible examination for himself. At the end of seven years' constant study, Professor De Candolle, from whom the description is translated, is able to state what the real characters of these plants are, and by putting his knowledge into this technical form, he renders it available for any other Botanist upon ten minutes' study.

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